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REFINEMENTS TO SERVICE RETENTION LIMITS FOR REPARABLE AERONAUTICAL COMPONENTS (INACTIVE INVENTORY)

December 2014

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**REFINEMENTS TO SERVICE RETENTION LIMITS FOR REPARABLE
AERONAUTICAL COMPONENTS (INACTIVE INVENTORY)**

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ABSTRACT

As aviation weapon systems progress through their acquisition life cycles, there is a natural fluctuation in the number of weapon systems in custody by the service components and the number of subsystems available to sustain operational availability. This thesis reviews current retention methodologies utilized in the Department of Defense, evaluates previous retention studies mandated by Congress, and proposes adjustments in the U.S. Navy retention algorithm of aeronautical components to reduce the stockpile of inactive inventory and generate cost savings. The proposed adjustments developed in this research complements the current life cycle indicator (LCI) utilized to discriminate aeronautical components in its inactive inventory. The main findings show that LCI retention policy can be refined by independently assigning LCIs to aeronautical components and coupling the LCIs with the newly developed *condition based logical retention* described in this thesis. The proposed adjustments can generate an optimized inactive inventory pool of aeronautical components for the U.S. Navy, that has the greatest value for an aircraft weapon system.

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LIST OF ACRONYMS AND ABBREVIATIONS

AAO	approved acquisition objective
COTS	commercial off-the-shelf
C&E	construction and equipment
C&T	clothing and textile
CPR	cube-price ratio
CRS	contingency retention stock
DLA	Defense Logistics Agency
DRMS	Defense Reutilization and Marketing Service
ECDR	expected cost to dispose or retain
ERL	economic retention level
ERP	enterprise resource planning
ERS	economic retention stock
FLIRR	financial and logistics integrated requirements report
GAO	Government Accountability Office
HF	high frequency
IMECY	item mission essentiality code year
MAUC	mean acquisition unit cost
MICAP	mission capability
MMM	metrics measurement module
PRS	potential reutilization stock
QFD	quarterly forecasted demand
RMC	returns method code
RMC-N	items with probable demand
RMC-R	items with predictable or forecasted demand
SS	serviceable stock
SSIR	supply system inventory report
US	unserviceable stock
YDR	years of demand-based retention
ZF	zero frequency

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I. INTRODUCTION

A. BACKGROUND

In the past four years, from 2010 to 2013, wholesale inventory retention for reparable aeronautical components in the categories of economic retention and contingency retention repairable assets has increased by 46.7 percent. Given the 2008 Government Accountability Office (GAO) report and the 2010 National Defense Authorization Act request for component services to review and validate methods used to establish retention requirements, the U.S. Navy seeks refinements to service retention limits, which regulates inventory growth and provide the utmost future value to existing weapon systems.

This thesis examines the service retention limits for aviation material assets in the U.S. Navy's wholesale inventory. The retention and reutilization of aviation material assets incorporates critical approaches for inventory retention decisions based on several policies managed by materiel managers assigned to Naval Supply Systems Command Weapon System Support (NAVSUP WSS), Philadelphia. The Secretary of Defense wholesale inventory policy for all service components and Defense Logistics Agency (DLA) states: "Under DOD's supply chain materiel management policy, the secondary item inventory should be sized to minimize DOD's investment while providing sufficient inventory to support both peacetime and war requirements" (Assistant Secretary of Defense for Logistics and Materiel Readiness [ASD(L&MR)], 2014, p. 26).

Acquisition objectives for aeronautical components follow strict guidance via statutory laws and policies set by the federal government and component services. One of these policies is Department of Defense Directive (DODD) 4140.1 Volume 6, titled *Supply Chain Materiel Management Procedures: Materiel Returns, Retention, and Disposition*, which specifically focuses on DOD wholesale inventory (ODUSD[L&MR], 2003).

The GAO conducted the last comprehensive assessment on the Navy's secondary inventory (wholesale) in 2008. The GAO's assessment team authors referenced DOD

4140.1 Volume 6 on their findings when they discovered “that, on average, DOD inventory was about \$11.3 billion (60 percent) of the total annual inventory value needed to meet current requirements, whereas \$7.5 billion (40 percent) exceeded current requirements” (GAO, 2008).

In 2008, the GAO concluded that ineffective management of active policies and the culmination of combat operations in Iraq greatly contributed to the 40 percent of inventory excess in the DOD. However, as of January 2009, the U.S. Navy’s inactive wholesale inventory composed a substantial part of the DOD’s inventory excess. Economic retention (ER) inventory was composed of 81,419 different line items (range) with around 1.7 million components (depth) valued at \$1,037,801 billion (GAO, 2008). The contingency retention (CR) inventory was composed of 26,052 different line items (range) with around 1.2 million components (depth) valued at \$321,923 million (GAO, 2008).

In 2010, Congress approved the National Defense Authorization Act (NDAA) and within the act, § 328, Element 4, tasks the DOD to “plan for the review and validation of methods used by the Military Departments and the Defense Logistics Agency to establish economic retention requirements.” In addition, § 328, Element 5, tasks the DOD to “plan for an independent review of methods used by the Military Departments and the Defense Logistics Agency to establish contingency retention requirements” (NDAA 2009).

B. PROBLEM IDENTIFICATION

This study examines existing economic retention analysis methodology and policies governing service retention limits to get an understanding of the structure, assumptions, and decisions that influence service retention limits in the U.S. Navy inactive inventory. This study also reviews the process for program-based requirements for the initial outfitting of aircraft, the management of aviation depot level reparable (AVDLRs) peculiar to ready mission sets, the performance of the weapon system, the operational availability of aircraft during sustainment, and ultimately the planning and execution milestones to sunset (retire) the weapon system.

C. RESEARCH PROJECT OBJECTIVES

This thesis focuses on four specific objectives:

1. Evaluate economic retention quantities requirements (ceilings and floors).
2. Evaluate contingency retention quantities requirements (ceilings and floors).
3. Recommend refinements to factors for life cycle driven retention.
4. Identify risk for adopting recommendations from this thesis.

Given the DOD's wholesale inventory size, the U.S. Navy's upward wholesale inventory trend, and NDAA 2010 time-sensitive congressional tasks to the DOD, the scope for this research is limited to reparable aeronautical components for the CH53E heavy transport helicopter. Results for each of the objectives represent a small sample of the inventory population (e.g., 986 NIINs). Additional factors may need to be considered before generalizing the effects of this research to other segments of the wholesale inventory.

D. SCOPE

The scope of this project is concentrated on the reparable aeronautical components assigned for the CH-53E heavy transport helicopter (aviation weapon system) wholesale inventory level. The CH53E aircraft was selected as the research object because of the ease of access to maintenance, demand, and reliability data as well as the aviation platform's mature state in the inventory system. The main objective of this research is to validate *acquisition advice codes and equipment operations capabilities codes* as an integral factor for the life cycle indicator (LCI) retention methodology. This research utilized maintenance data from Commander, Naval Air Systems Command PMA-261, Integrated Logistics Support Management System (ILSMS), and final *Financial and Logistics Integrated Requirements Report* (FLIRR) cycle related to the March 2014 stratification cycle (Buhrman, 2013a).

This research validates service retention limit (SRL) calculations with emphasis on the economic retention quantity (ERQ) requirements. We scrutinize analysis and evaluation of ERQ requirements for the life cycle of the sub-system independently of the CH-53E weapon system, commencing with all acquisition milestones for initial

operational capability (IOC), pre-material support date, full operational capability (FOC), material support date (MSD), demand development interval, maturity, and eventually retirement.

E. VALUE ADDED FOR U.S. NAVY

The findings from this study can contribute to cost savings for the U.S. Navy secondary inventory (wholesale), mainly through better retention limits when adaptation of new algorithms for economic retention quantities are coded in ERP, probabilities for future repurchase events are mitigated, and new policy shifts contingency retention quantities (CRQ) from a managerial model to a quantitative model.

II. BACKGROUND

A. INTRODUCTION

The purpose of this project is to examine and recommend improvements for the U.S. Navy's secondary inventory (wholesale) service retention limit (SRL) calculations, with specific emphasis on economic retention quantity (ERQ) for aviation depot level repairable (AVDLRs) throughout the life cycle of an aviation weapon system.

The DOD and each of its military services are constrained by fiduciary statutory laws, policies, and a defense base budget that in 2014 is \$3.9 billion less than the 2013 base budget (NDAA, 2014). Commander, Naval Supply Systems Command (NAVSUPSYSCOM), seeks to improve SRLs, which are composed of economic retention quantity (ERQ) and contingency retention quantity (CRQ).

Two reports support the requirement for NAVSUPSYSCOM to seek a better alternative for its SRL calculations. First, the GAO (2008) issued a report titled *Management Actions Needed to Improve the Cost Efficiency of the Navy's Spare Parts Inventory*. Second, the National Defense Research Institute Review (2013), a RAND affiliate, issued a report titled *Improving Repairable Item Supply Chain Management*.

The GAO and RAND reports provide empirical evidence for inventory "designs" that lack feedback-oriented control systems to weapon systems program managers. According to the GAO, inventory designs that leads to excess inventories and become the object for support, have always resulted in unexpected higher holding cost, and unmanageable inventory quantities (GAO, 2008).

B. U.S. NAVY RETENTION AND REUTILIZATION OF MATERIAL ASSETS

Tremendous foresight is required in the acquisition of a new aviation weapon system. In most cases, procurement of aviation weapon system begins with a mission needs statement to the Joint Requirement Oversight Council (JROC). On average, there can be up to two decades of lag time between the approval of a mission needs statement and the production of an aviation weapon system.

For example, JROC approved the mission needs statement for the V-22 Osprey in 1981. The first V-22 Osprey was produced in 1998 and had its first test flight in 1999. Today, there are 12 integrated product support (IPS) elements, and the inability to meet one of the 12 PSEs may extend the acquisition process of an aviation weapon system. According to Farmer's own studies, research, and observations into acquisition processes:

The broad scope of statutory and regulatory requirements, the push for transformational capabilities, and the complexity of new systems often make the standard acquisition process lengthy. It can take as long as 12 to 25 years to move from concept to initial operational capability (IOC). (Farmer, 2012, p. 12)

The Defense Acquisition System (DAS) is the source of guidelines and policies followed by the DOD in the acquisition of aviation weapon systems. The concepts and set of beliefs are simple: to have a low-risk process focused on cost, schedule, and performance. These acquisition guidelines and set of beliefs have been published in the DOD 5000 series since 1971. The objective of the DAS is to incorporate into DOD 5000 a process that can be supported and is affordable throughout the life cycle of a weapon system. As shown in Figure 1, the acquisition system also includes planning programming, budgeting, and execution (PPB&E) as well as the joint capabilities integration and development system (JCIDS).

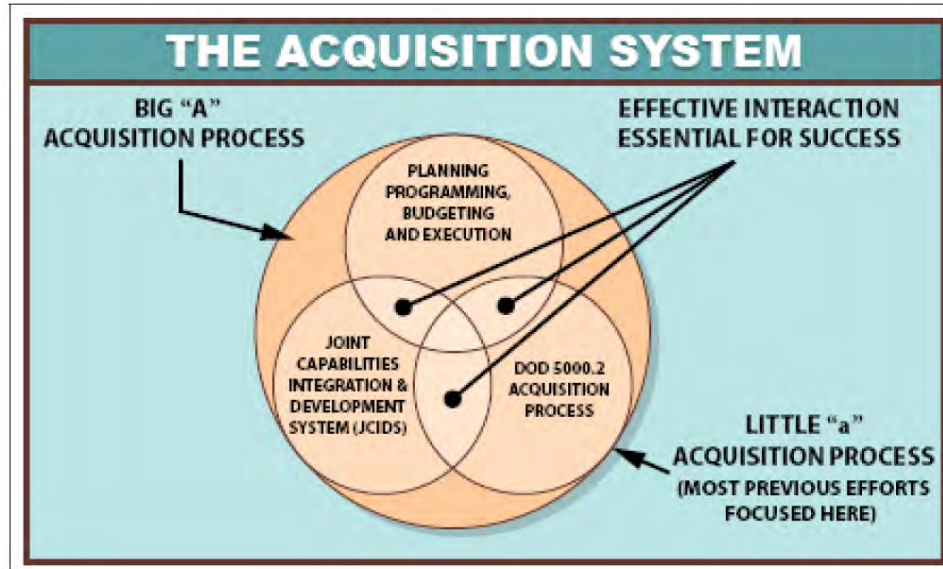


Figure 1. DOD's Defense Acquisition Structure (from JCIDS Process, 2014)

However, the process to purchase a weapon system that meets specific military requirements must also meet statutory and regulatory requirements:

Title 10 of the United States Code governs the organization, structure, and operation of the Armed Forces of the United States. Several sections within the title charge the secretaries of the military departments (Army, Navy, and Air Force) with responsibility to "equip" the armed forces. (Schwartz, 2014, p. 35)

There is a three-step process in the acquisition system to field an aviation weapon system from concept to deployment. The three-step process is as follows: (1) requirements identification: Joint Capabilities Integration Development System (JCIDS); (2) resources and budgeting identification: planning, programming, budgeting, and execution (PPB&E); (3) acquisition process (DOD 5000 series).

The DOD's service components are required to review their service retention limits annually in terms of cost and other factors. The focus of this review is to retain only those stocks that are based on approved economic methods. Economic analysis must balance the costs of retention, disposal, and potential repurchase. For aviation weapon systems items, economic retention levels will depend on changes in the number of approved systems in use if the future demand rate per system is predictable; if probable,

there has to be a justifiable rationale in writing to keep the sub-system as economic retention. Current or greater retention levels may be warranted in the following cases: (1) the change in the number of systems is due to weapon system phase out (new lot), (2) future demand rates for items are expected to increase due to aging, or (3) there is a possibility of diminishing manufacturing sources (ASD[L&MR], 2014b, p. 16). Table 1 provides additional considerations for retention levels.

Table 1. Provision Consideration for Retention Levels

cost of storage capacity	material cost
potential long-term demand	expected life of the system/subsystem
potential repurchase procurement	number of systems in use

The service components review their service retention limits (SRLs) with the objective to seek optimal solutions. It is important to understand the meaning of ERQ and CRQ and the exact fit of those concepts in the overall DOD's defense acquisition and inventory policy structure. The economic retention stock assessment reference checklist (Appendix D) provides structure and criteria for economic retention considerations. According to guidance from the assistant secretary of defense for logistics and material readiness:

Inventory managers do not purchase inventory for the purpose of stocking as economic retention (ASD [L&MR], 2010, p. 5–2).

Stratify stock above the AAO [approved acquisition objective] level as ERS if it is more economical to retain than to dispose and then potentially repurchase. To warrant economic retention, an item will have a reasonably predictable demand rate. If the expected demand for an item is probable but not predictable, the item may be considered as ERS, provided that the managing DOD component has documented rationale that economically justifies retention and is available for audit purposes. (ASD[L&MR], 2014, p. 15)

Stratify stock above the AAO and ERS as CRS if a level has been established that is held to support specific contingencies. To warrant

contingencies retention, the materiel manager must provide rationale to warrant contingency retention (from ASD[L&MR], 2014, p. 16).

CRQ is defined as materiel assets above the AAO and above the ERS level that are held to support specific contingencies. To warrant stockage as CRQ, the inventory manager must provide rationale that associates CRQ to a military contingency, security assistance, or general contingency (ASD[L&MR], 2010).

Strict guidance by the DOD requires service components to conduct annual reviews of cost, demand, weapon system, and other factors to ensure they are up to date. Senior executive service management will attest to the validity of the factors in writing and approve retention decisions (ASD[L&MR], 2014, p. 16). Table 2 identifies the six different categories of CRQ:

Table 2. Contingency Retention Stock Categories of Classification (from ASD[L&MR], 2014, p. 16)

<u>CRQ CODE : BRIEF DESCRIPTION</u>	<u>CRQ CODE : BRIEF DESCRIPTION</u>
Code “C”: Reclamation and cannibalization	Code “F”: Potential Security Assistance-FMS reserve
Code “H”: Humanitarian Assistance and disaster relief, to include civil emergencies	Code “M”: Military Operational Necessity
Code “P”: Item procurement and re-procurement constrained, includes diminishing manufacturing source life-of-type buy, non-procurable stock, un-forecastable demand, performance based logistics (PBL) item.	Code “W”: Weapon system exclusion, includes weapon system modification programs, service life extension programs, and weapon systems designator codes item.

In summary, the scope of this project is focus on CH53E repairable aeronautical components with the objective to validate *acquisition advice codes and equipment operations capabilities codes* as additive factors for the LCI retention methodology. The goal is to examine the effects additive factors have on inventory quantities for service retention limits.

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III. LITERATURE REVIEW

A. INTRODUCTION

In the past two decades, the DOD has established inventory systems in support of the national defense strategy's full range of military operations (ROMO). Given the uncertainties of real-world conflicts, fast-paced technological advances, and two regional wars in the Middle East, these inventory systems have been very effective but not efficient. Today, budgetary constraints and congressional mandates require component services to review their inventory strategies/posture to support future military operations.

Aviation weapon systems have particular requirements for provisioning spares under the Joint Capabilities Integration and Development System (JCIDS). This chapter reviews JCIDS requirements, DOD inventory standards and policies, and RAND Corporation and Logistics Management Institute (LMI) inventory studies and reports.

DOD spare parts inventory has two basic categories: active (funded) and inactive (not funded); see Figure 2. The first category is the active approved acquisition objective (AAO) inventory. The second category is the inactive inventory, which is stratified into three subcategories: economic retention quantity (ERQ), contingency retention quantity (CRQ), and potential excess quantity (PE).

The focus for this literature review is the inactive inventory. The primary objective is to improve the current LCI methodology for ERQs and CRQs. The secondary objective is to find commonalities and differences among the published inventory studies. Additionally, the tertiary objective is to comprehend how the U.S. Navy ERQ/CRQ retention policy supports DOD guidance.

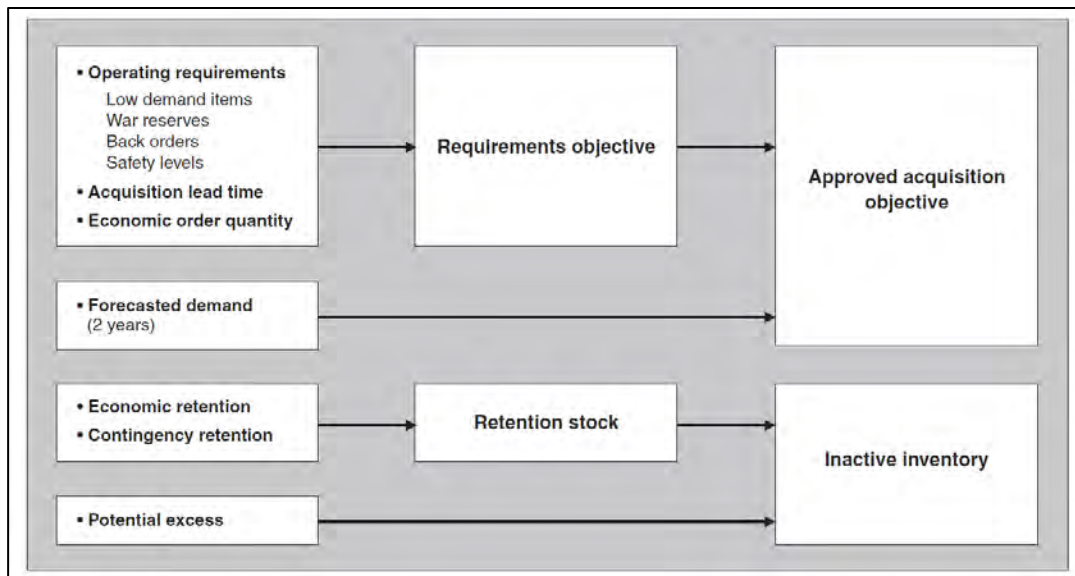


Figure 2. Categories of DOD Spare Parts Inventory (from GAO, 2010, p. 13)

B. DOD STANDARDS FOR STOCK RETENTION LIMITS

DOD policy requires materiel managers to use economic analysis to determine economic retention stock (ERS) levels. DOD (1995) Instruction DODI 7041.3, *Economic Analysis for Decision-making*, provides guidance on conducting an economic analysis assessment. Materiel managers must efficiently manage their time and their primary responsibilities, which are to provision, catalog, acquire, determine requirements, distribute, maintain, and dispose of items under their responsibility. The overarching policy of DODI 7041.3 to establish requirements for conducting economic analyses as well as to describe materiel managers' primary responsibilities. However, given the guidance outlined in DODI 7041.3, there was no evidence found among the 42 documents reviewed to suggest that item managers, service components, or the Defense Logistics Agency (DLA) adheres to the type of economic analysis required. This study finds subsequent policies written in support of economic analysis authored by service components and DLA, which range from ambiguous to very prescriptive.

Since 1994, each of the component services and the DLA have developed and adopted their own economic analysis policies, logic, and algorithms to determine economic retention levels. DODI 4140.1R Section C2.8 requires materiel managers to

follow procedures governing economic retention. (Office of the Deputy Under Secretary of Defense for Logistics and Materiel Readiness, 2014) However, the U.S. Navy has coded its economic retention and contingency retention policies into the Navy's information system (Enterprise Resource Planning [ERP]) as a "plug-in" task that executes modified mathematical algorithms (see Appendix B).

Navy materiel managers continuously work with unreliable forecast demand data. Economic analysis for stock retention with unreliable "future demand" introduces the risk of disposing an aeronautical component and then later having to repurchase it. "The risk and costs associated with disposing of and then repurchasing material far outweigh the cost of retaining the stock" (Pouy, Kim, Sigalas, & Zimmerman, 2007, p. 17).

The function for possessing aeronautical components in the inactive inventory is to fulfill a probable demand in a future time horizon. Materiel managers must evaluate two types of risk: first, the risk of having to repurchase a component that has been disposed of and second, the risk of keeping a component with zero forecasted demand in the established time horizon.

Support for a new aviation weapon system commences with provisional engineering data. The integrated weapon systems team (IWST) lead and materiel managers must continuously communicate with the weapon systems' aviation program managers for logistics (APML) to reconcile significant deviations from the provisioning plan and update any significant changes to sub-systems' reliability performance.

A critical document that supports the weapon systems' sub-systems is the Life Cycle Support Plan (LCSP). The LCSP is a living document written during the planning/concept phase that provides logistics support requirements (supply support/spare parts) to be acquired, produced, delivered, and phased-out with an integrated schedule for the weapon system. Section D in this chapter provides additional LCSP information and explains how the LCSP is integrated into the Joint Capabilities Integration and Development System (JCIDS) acquisition process.

Given the high number of configuration changes during the first five years of a new aviation weapon system, it is critical to understand how these changes affect the original provision for spare parts. The LCSP bridges this requirement. According to the GAO, “Configuration changes may be made to the system or parts may last longer or shorter than initially estimated. As a result, some items that are purchased based on the initial provisioning estimates are ultimately not needed to meet requirements” (2008).

Therefore, DOD requirements for economic stock retention (ESR) and contingency stock retention (CRS) must be reconciled with the aviation weapon system’s maintenance plan and the LCSP. A sound reconciliation ensures that retained aeronautical components can be used to fill future AAO requirements, that is, cage/part numbers are authorized in the aircraft. According to Zimmerman (2003),

Retention decision determines how much stock above the maximum required level should be retained as ERS and how much should be disposed of. As such, the economic retention limit is not a requirement-based level like the safety level or order quantity. It is not a level required to support normal operations. The stock being retained can preclude or reduce future procurements or repairs and the stock being disposed of are not available to preclude or reduce future procurements or repairs. (2003, p. 1–3)

Section C2.8 of DODI 4140.1-R provides specific guidelines for economic and contingency retention quantities:

C2.8.1.1.1.2. ERS is stock above the AAO that is more economical to retain than to dispose of. To warrant economic retention, an item should have a reasonably predictable demand rate. If the expected demand for an item is not predictable, yet the expectation for future demand is probable, the item may still have ERS provided the managing DOD component has a documented rationale that economically justifies retention and is available for audit purposes.

C2.8.1.1.2.A. To ensure that economic and contingency retention stocks correspond with current and future force levels, the DOD components shall review and validate their methodologies for making economic and contingency retention decisions. The review shall occur at least annually, and the inventory manager, organization commander, or designee shall attest to its validity in writing. (ODUSD[L&MR], 2013)

The basis for a comprehensive retention quantity is an economic analysis that inherently evaluates cost of retention versus the cost of disposal. According to Zimmerman:

ER is used as a hedge against demand and lead-time uncertainty, DOD decided not to dispose of all stock above computed requirements that can change. Instead it established an economic rule for retaining stock above changing requirements to minimize wasteful disposal and maximize the use of its investments in inventory. (Zimmerman, Pouy, & Burleson, 2009, p. 2–3)

The DOD has published specific guidelines for analytic studies and has mandated use among service components and DLA. The six most important guidelines are as follows:

1. DOD Instruction 7041.3 (DOD, 1995)—Weapon systems and weapon Systems support, analytic studies that deal with cost and effectiveness considerations in those areas are considered to be “economic analyses” and should adhere to DODI 7041.3, enclosure (3), and DODD 5000.1 and 4275.5, references (d) and (e) respectively.
2. Time horizon: The life of an item is assumed to be 20 years (DOD, 1995)
3. Discount factor = Nominal Discount Rate at 2.9 percent (DOD, 1995)
4. The mean acquisition price is used vice the “unit price” (DOD, 1995)
5. The “holding cost” must be computed as 1 percent of the acquisition cost (ODUSD[L&MR], 2003).
6. The salvage rate (Disposal Revenue) is 1–2 percent of the acquisition cost (ODUSD[L&MR], 2003).

Although the DOD publishes these guidelines, it does not have self-evaluating metrics to assess how well these mandates are adhered by service components and DLA. In practice, the DOD allows each service component to derive their own methodology procedures. Since 1994, there have been over 19 studies in support of DOD inventory processes improvements. Congress has mandated additional studies as a result of inspector general or GAO reports.

C. REVIEW OF ECONOMIC RETENTION STUDIES

DOD service components and DLA use economic retention models that are different from those described in DOD 4140.1-R regulations (ODUSD[L&MR], 2003).

Given § 362 of the NDAA for fiscal year (FY) 2000, which mandated a study for reparable components into the ideal retention analysis process in terms of number of years and saving computation, the following RAND / Logistics Management Institute (LMI) studies were reviewed.

In 2003, LMI completed the mandated study by Congress; Figure 3 displays some of the salient findings and recommendations of their reports:

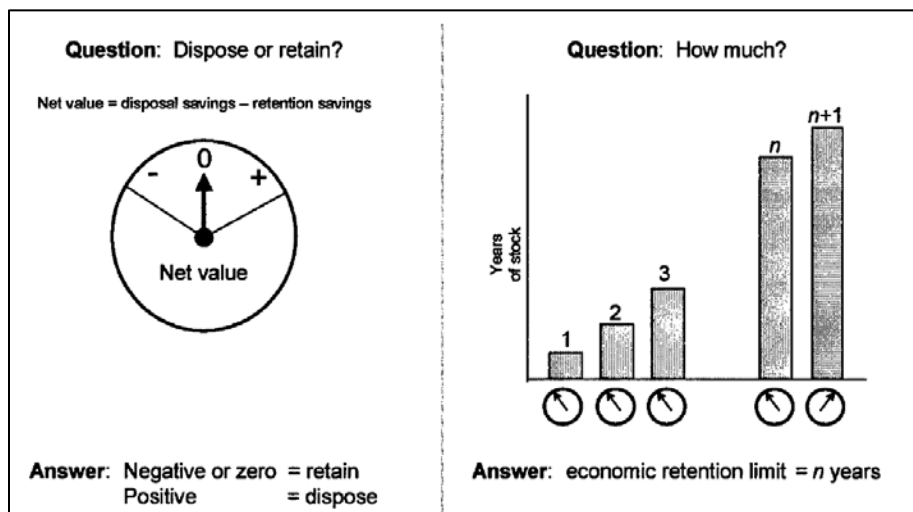


Figure 3. LMI Basics for Retention Analysis (from Zimmerman, 2003)

According to Zimmerman (2003), the recommendation to dispose and retain is expressed as a function of discount factors:

Starting with year 1, use discount factors to express the present value of savings if stock is retained and the present value of savings if stock is not retained or is disposed. Subtract the present value savings for retaining stock from the present value savings for disposing of stock to arrive at the discounted net value. If the discounted net savings are positive, add 1 to the number of years and compute a new discounted net value. If this value is negative, subtract 1 from the number of years to arrive at the optimal number of years. (p. 2-5)

Figure 4 is an illustration for retention limits savings and costs and Figure 5 describes the savings computation for reparable components:

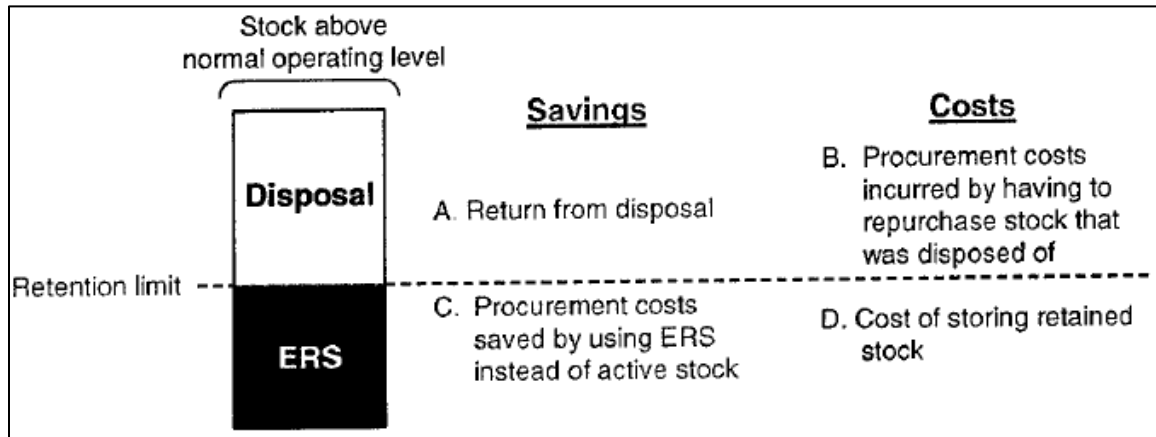


Figure 4. LMI Retention Decision for Savings and Costs (from Zimmerman, 2003)

Cost element	Hypothetical value	Reparable unit	Non-reparable unit
A. Acquisition price	\$1,000	Included	
B. Repair cost/price	\$200	Included	
C. Difference in price (A-B)	\$800		Included
D. Percentage of demands without turn-ins	20%	Included	Included
E. Percentage with turn-ins	80%	Included	Included
F. Percentage repaired	90%	Included	
G. Percentage condemned	10%	Included	Included
Estimated savings for each unit retained and used to fill demand	Formulation Value	$A \times (D + E \times G) + B \times E \times F$ \$324.80	$C \times (D + E \times G)$ \$224.00

Figure 5. LMI Demonstration of Reparable Savings Computation (from Zimmerman, 2003)

Also in 2007, the LMI conducted a different study and proposed to the DOD the mathematical model shown in Figure 6 to conduct and evaluate retention levels.

$$\begin{aligned}
& \text{If } ECR(N) > ECD(N) \text{ or } ECR(N) - ECD(N) > 0, \\
& \text{then } s \cdot up \sum_{j=1}^H \frac{1 - F_N(j)}{(1+i)^j} - \left(-v \cdot up + \sum_{j=1}^H \frac{up \cdot f_N(j)}{(1+i)^j} \right) > 0, \\
& \text{and } up \cdot \left[s \sum_{j=1}^H \frac{1 - F_N(j)}{(1+i)^j} + v - \sum_{j=1}^H \frac{f_N(j)}{(1+i)^j} \right] > 0.
\end{aligned}$$

Figure 6. LMI Economic Analysis Model (from Pouy et al., 2007, p. 6)

According to Pouy et al. (2007),

We exercised the model by starting with a small retention limit, then raising it incrementally until the cost to retain the next unit or quantity becomes greater than the cost to dispose. Since the price up is never negative, and no other variable is item specific, the sign of the expression, and therefore the economic retention limit, is independent of the item cost. Therefore, we can determine the economic retention limit for a group of items using only their collective depletion probabilities. (p. 6)

A possible retention model for reparable items developed by the LMI takes into consideration the frequency of demand in two-year cycles. The LMI tested possible combinations of factors for economic retention; some of the factors are as follows (see Appendix E):

- limits by condition (i.e., different limits for serviceable stocks [SSs] and unserviceable stocks [USs]);
- limits based on demand for both SS and U.S. or based on demand for SS and condemnations for US;
- limits assigned by frequencies of demand or condemnations, that is,
 - high frequency (HF)—demands or condemnations in each of the last two years,
 - medium or low frequency (MF or LF)—demands or condemnations in only one of the last 2 years, and
 - zero frequency (ZF)—no demands or condemnations in the last two years.

The LMI's 2003 study of DOD retention concludes that it is most economical in the long run to retain all material until it is obsolete. A program that considers replacement costs, holding costs, criticality, and several years' worth of demand can still achieve considerable savings. The least economic program is one that retains material solely based on demand, as the organization may later be required to re-procure material at a high cost. However, in FY 2004 and FY 2005, there were 2,235 "real" demands for the universe of material that would have been disposed of in 2003. There was \$32.26 million in repair/re-procurement costs, with the assumption that material could still be acquired at "replacement" price, not standard price. Average backorder-age was greater than five quarters (Gibbons 2006, p. S-11).

In 2009, LMI researchers developed a different approach. They introduced a depletion probabilities mathematical model for "aviation" economic retention limits. They assigned baseline cost factors of 1 percent holding cost, 2 percent salvage value, and 2.9 percent discount rate. One key factor for their approach was a multiple of demand forecast and year of attrition demand (see Appendix C).

Neither of LMI's 2003, 2007, or 2009 studies have a mathematical approach that considers the life-cycle cost by sub-component for the weapon system. The LMI reports reached conclusions from an economic analysis via a "stove pipe" perspective that best suits the inventory profile for the year analyzed. Also, the LMI claimed that "among the DOD components managing secondary items (i.e., the military services and the Defense Logistics Agency), only the Army uses a mathematical model to determine economic retention limits (ERL)" (Pouy et al., 2007, p. iii). There was no evidence in the literature reviewed to suggest that the other service components have a heuristics approach to their economic analysis requirements. To the contrary, mathematical models were used with sufficient analytic tools for material managers to retain.

These studies reflect a clear distinction among the service component management for their respective SRL methodologies. Nevertheless, naval aviation items showed more aggressive depletion rates than Army, Air Force, or DLA items. More than 70 percent of items would deplete eight years of stock in 10 years or less, and about 47

percent of items would deplete 12 years of stock in that time. Figure 7 illustrates the naval aviation depletion rates (Pouy et al., 2007, p. 14).

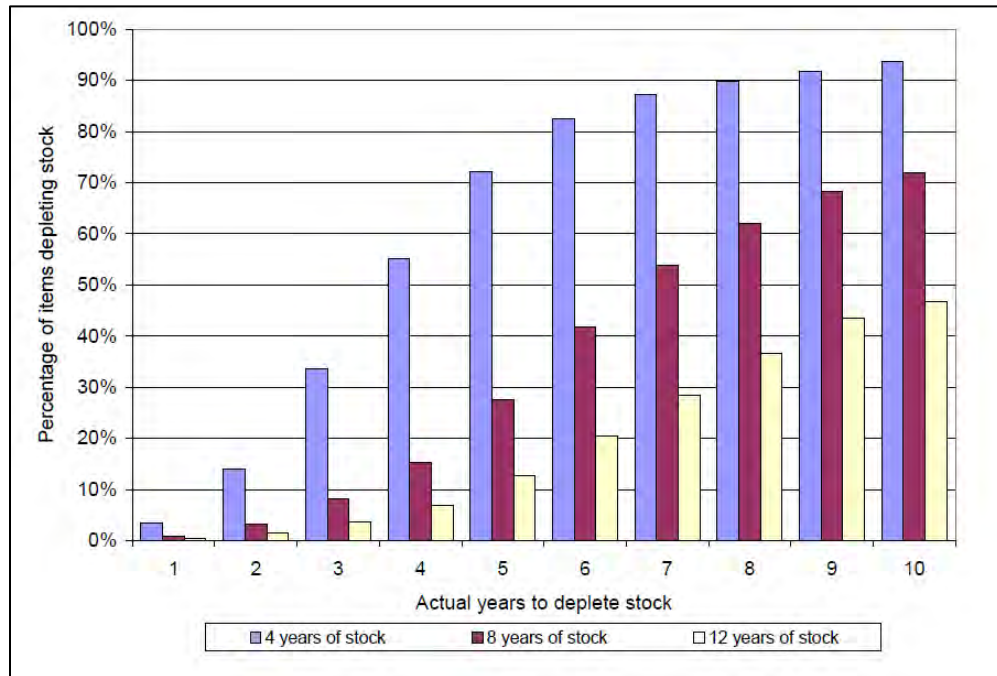


Figure 7. Naval Aviation Depletion Rates (from Pouy et al., 2007)

However, there was no evidence that the results of the aggressive depletion rates could be attributed to sound economic analysis policies; some of the effects were due to the timing during which the report was conducted (i.e., data was gathered during the phasing-out period of type-model-series aircraft from the Navy's inventory, such as the F-14s and CH-46s).

Nevertheless, among all the literature reviewed, high demand variability was the root cause for the constant fluctuation levels of the active inventory. Accumulation of aeronautical components in the inactive inventory is the direct result of the AAO shifting below the previous year targets; it is not part of the retention decision methodology.

There is a clear cause-and-effect relationship between ERS and CRS. Economic retention is based on cost effectiveness, not contingency support. In addition, economic retention is not subject to transfer to Defense Reutilization Management Services

(DRMS), and most importantly, economic retention is not a budget requirement (Zimmerman et al., 2009, p. 2–2).

The Defense Logistics Agency uses the mathematical methodology shown in Figure 8 for retention levels (Zimmerman et al., 2009, p. 3–11).

The expected marginal cost to dispose for a retention level of N units is

$$ECD(N) = -v \cdot up + \sum_{j=1}^H \frac{up \cdot f_N(j)}{(1+i)^j};$$

and the expected marginal cost to retain for a retention level of N units is

$$ECR(N) = s \cdot up \sum_{j=1}^H \frac{1 - F_N(j)}{(1+i)^j},$$

where

N	=	number of units in the retention level
$ECD(N)$	=	expected marginal cost to dispose for level N
$ECR(N)$	=	expected marginal cost to retain for level N
up	=	unit price (acquisition cost)
v	=	salvage cost factor

H	=	number of periods in the time horizon
$f_N(j)$	=	probability of depleting level N in period j
$F_N(j)$	=	probability of depleting level N by period j
i	=	discount rate
s	=	storage cost factor (as a percentage of item dollar value)
p	=	premium (percentage) for repurchasing materiel

Figure 8. DLA Mathematical Methodology (from Zimmerman et al., 2009)

Between March FY 2013 and September FY 2013, retention inventories increased by 10.8 percent (\$0.4 billion), as shown in Figure 9 (National Defense Research Institute, 2013).

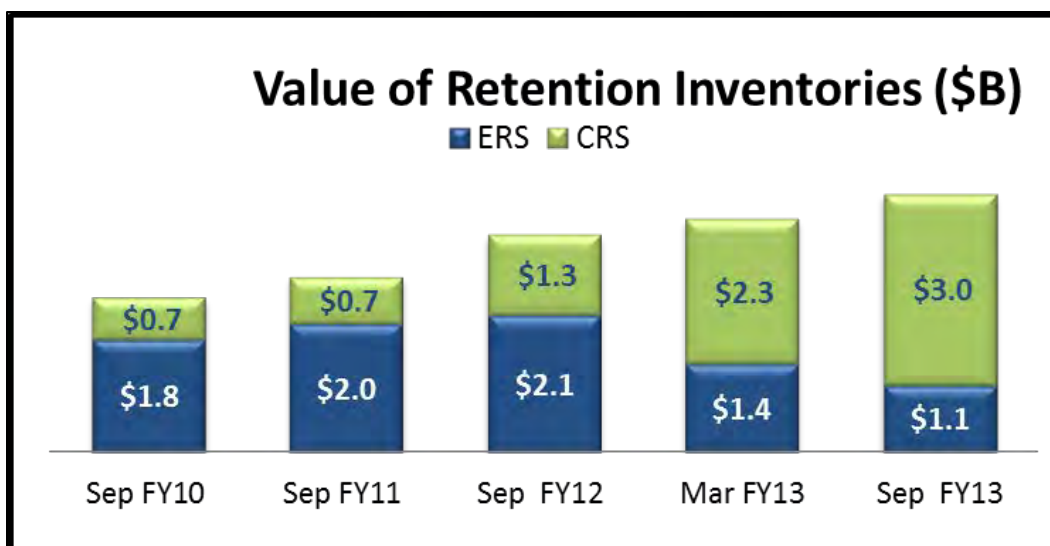


Figure 9. DOD Stock Retention Value (from National Defense Research Institute, 2013)

The National Defense Research Institute (2013) provided the following findings in its report:

DOD on-hand secondary item inventory: \$98B on-hand vs. “should-be” of \$42B. (DOD inventory stratification snapshot) Repairable account for 75% of secondary item inventory held in DLA depots, with this inventory turning once every 2.6 years. Additional stock held at retail / intermediate levels DLR Disposals/year (05-12): \$5.1B condition code “F” & \$1.4B serviceable. (p. S-2)

Figure 10 provides the itemized stratification of inactive inventory with the different contingency code designations. One key observation during this research was the lack of specific documented rational to justify retention.

\$Billions	Sep FY10	Sep FY11	Sep FY12	Mar FY13	Sep FY13
Economic Retention	\$1.76	\$2.00	\$2.14	\$1.38	\$1.06
Contingency - LOT/DMSMS above the AAO and ERS	\$0.08	\$0.11	\$0.05	\$0.02	\$0.01
Contingency - Potential Humanitarian Relief	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00
Contingency - Potential Security Assistance	\$0.14	\$0.15	\$0.37	\$0.41	\$0.80
Contingency - Part Source/Cannibalization	\$0.04	\$0.07	\$0.01	\$0.12	\$0.16
Contingency - Potential Weapon System Modernization	\$0.29	\$0.28	\$0.50	\$0.02	\$0.02
Contingency Military Essentiality	\$0.12	\$0.13	\$0.33	\$1.72	\$1.99

Figure 10. Itemized DOD Stock Retention Value (from National Defense Research Institute, 2013)

D. U.S. NAVY INVENTORY PROCESS REVIEW

The U.S. Navy has an enterprise process to determine the AAO. First, during the requirements objectives (RO) process, operating requirements, acquisition lead-time, economic order quantity, reorder point factors for safety stock, and on-order inventory are reviewed. Second, the forecasted demand is reviewed based on two years of demand history. Collectively, these processes constitute the *active inventory* or AAO (GAO, 2008, p. 7).

Active inventory is outside the scope of this thesis. However, the Navy's retention policy for inactive inventory depends on the status of the weapon system to which the item for retention applies.

Inactive inventory is defined as material that is not expected to be consumed within the budget period (two years) but is likely to be used in future years. Any registered user or the inventory materiel managers (IMMs) define an inactive item as an item without a wholesale demand in the last five years for which no current or future requirements are anticipated. (Office of the Under Secretary of Defense for Acquisition and Technology, 2003)

Figure 11 is the U.S. Navy's overarching retention policy from which the life cycle indicators are defined. However, in some literature the U.S. Navy refers to retention

limits applied to specific aeronautical components whereas the application shown in Figure 11 is for the weapon system.

Weapon system status	Retention limit (years of attrition demand)	Minimum retained (floor)
Ascending	12 years	5 each
Steady	8 years	3 each
Declining	4 years	1 each

Figure 11. Navy Retention Policy (from Pouy et al., 2007)

Weapon systems are categorized as ascending, steady, or declining, depending on the state of the weapon system's life cycle. The policy applies a years-of-supply rule and a minimum floor rule (Pouy et al., 2007, p. 6).

The NWCF-SM stock retention calculations come from NAVSUP Instruction 4500.13A dated October 2013 (see Appendix A). The policy defines and outlines wholesale stock retention limit calculations. First, it calculates each item's AAO and ERQ, sums both of them and a life-cycle indicator is applied to obtain an item's ceiling and floor parameters. The ceiling threshold is applied on a basis of demand over a period of time, and floor threshold is applied as a set quantity based on life-cycle phase of the weapons system. Economic retention quantity is then derived as the balance of ceiling years minus AAO (NAVSUP, 2013, p. E-2).

Materiel managers use the ERQ algorithms incorporated into the Enterprise Resource Planning (ERP) to determine economic retention limits (see Appendix B). The mathematical logic embedded in ERP does not result in an economic analysis described by DOD memorandum, *Supply Chain Materiel Management Procedures: Materiel Returns, Retention, and Disposition*, dated February 2014. Economic analysis inherently evaluates cost of retention versus the cost of disposal. According to Zimmerman et al. (2009),

ER is used as a hedge against demand and lead-time uncertainty. DOD decided not to dispose of all stock above computed requirements that can change instead, it established an economic rule for retaining stock above

changing requirements to minimize wasteful disposal and maximize the use of its investments in inventory. (p. 2-3)

The scope for this research project is the CH-53E heavy lift helicopter and its repairable aeronautical components. However, during this literature review, there was a clear observation of how the process deviates from DOD policy for economic retention stock. The DOD basis for economic retention is cost-effectiveness. According to Zimmerman (2003),

If the retention of stock saves the government money, it should be retained. If it does not, it should not be retained and is not ERS. As stated in DOD 4140.1-R, the setting of ... the maximum level of ERS for an item should be based on an economic analysis that balances the costs of retention and the costs of disposal. (p. 2-4)

The CH-53E is a platform with an inventory of approximately 200 aircraft. Today, the aircraft as a weapon system is in a mature life-cycle stage (LCS), however, some of the aircraft's subsystems can be new (ascending LCS), mature (steady LCS), or obsolete (declining LCS). The new systems provide mission enhancement capabilities required for the mission essential tasks. Also, according to Zimmerman (2003), there are additional considerations:

AVDLRs have an additional level of complexity to economic retention decisions for two reasons. First, whenever demand is placed for a repairable component, a serviceable asset is exchanged for an unserviceable asset. That is, the unserviceable asset at the wholesale inventory may not be immediately inducted for repair. If the unserviceable asset [F condition] is disposed and later needed, a future repurchase cost would be incurred. Consequently, attrition, not demand, drives the retention decision for repairable items. Second, if the unserviceable asset is held and later needed to fill a demand, a repair cost would be incurred before it could be issued. Therefore, the repurchase cost for a repairable item is the difference between the replacement cost and the repair cost (p. 18).

There are many variations for economic analysis to evaluate the cost of holding (retaining) aeronautical components, compared with the cost of disposal and subsequent repurchase. However, AAO levels are the source for all retention considerations. Variation in demand forecast has the greatest impact to AAOs. Retention consideration

acknowledges the variability in demand as well as other factors. According to the GAO (2008) in one of their interviews:

According to Navy managers, demand is the single most significant data element for forecasting requirements and a driving factor in identifying the reorder point. While Navy managers agreed that accurately forecasting demand is a long-standing difficulty, they said that they forecast demand as best as they can and could not readily identify ways to significantly improve on their current procedures. (p. 20)

One of the top priorities for the DOD is decreasing the depth, range, and inventory value for its inactive inventory:

While \$11 billion of the DOD inventory is at retail supply activities close to the military customers it supports, \$74 billion is wholesale inventory held primarily in 25 distribution centers around the world, mostly in the continental United States, and occupies more than 100 million cubic feet of storage space. (Pouy et al., 2007, p. 2)

High demand variability adversely affects all inventory decision-making, causing stock buys that are too big or too small, excesses and shortages in on-hand inventories, and the premature release of material to disposal. High demand variability is also why retention limits are so important to the DOD and why they warrant the periodic retention analyses dictated by DOD policy (Zimmerman, 2003, p. 1-10).

According to Navy managers, demand is the single most significant data element for forecasting requirements and a driving factor in identifying the reorder point. One of the most important findings according to Navy materiel managers was the lack of timely communications among stakeholders, including the neglect of program managers to promptly relay changes in programs and other decisions that affect purchases of spare parts (GAO, 2008, p. 20).

The increased retention level for inactive inventories supports a hypothesis that “material managers are being conservative and erring on the side of retaining more stock for the items they manage” (Zimmerman, 2003, p. v). However, stock retention limit calculation is limited to the sum of AAO plus ERQ plus CRQ.

E. JOINT CAPABILITIES INTEGRATION AND DEVELOPMENT SYSTEM

Established in 2003, the Joint Capabilities Integration and Development System (JCIDS) replaced the Requirements Generation System (RGS), which was an identification model that was thread-based and service driven (Schwartz, 2014). The Chairman of the Joint Chiefs of Staff (CJCS) governs the JCIDS process, and CJCS (2012) Instruction 3170.01H mandates that the first step for a Major Defense Acquisition Program (MDAP) is to conduct a Capability Based Assessment (CBA).

The CBA reviews current capabilities and recommends a material or non-material solution to the proposed requirement. As part of the JCIDS process checks and balances, the Joint Requirement Oversight Council (JROC) approves or disapproves acquisition/investment requirements based on the CBA recommendations. A key deliverable of the JCIDS process is to determine whether a material or non-material solution would best meet the requirements gap analyzed and written in the Initial Capabilities Document (ICD). According to Defense Acquisition University's (DAU, 2014) JCIDS process:

The ICD defines the gap in terms of the functional area; the relevant range of military operations; desired effects; time; Doctrine, Organization, Training, Materiel, Leadership and education, Personnel, and Facilities (DOTMLPF) analysis; policy implications and constraints. The outcome of an ICD could be one or more DOTMLPF Change Recommendations (DCRs) or Capability Development Documents (CDD).

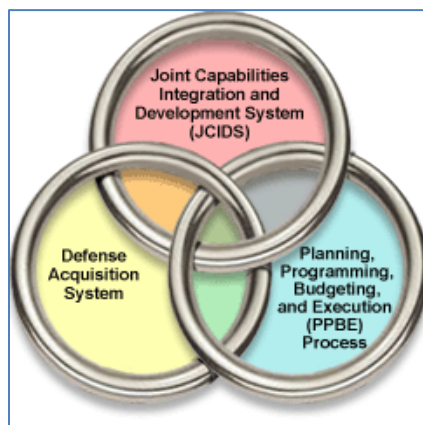


Figure 12. DOD's Decision Support System Acquisition Structure (from JCIDS Decision, 2009)

1. Funding

The Office of the Secretary of Defense (OSD) reviews each program objective memorandum (POM) and makes a decision to approve or disapprove proposed weapons systems via the planning, programming, budgeting, and execution (PPBE) process. The POM is decided upon concurrently with the planning phase for the program. According to DOD I 5000.2,

The planning phase of PPBE begins with OSD and the Joint Staff collaboratively articulating resource-informed national defense policies and military strategy known as the Strategic Planning Guidance (SPG). The SPG then leads the “Enhanced” Planning Process (EPP). The result of EPP is a set of budget-conscious priorities for program development (military force modernization, readiness, and sustainability; and supporting business processes and infrastructure), and is written-up in the Joint Programming Guidance (JPG). (Under Secretary of Defense for Acquisition, Technology, and Logistics [USD(AT&L)], 2003)

2. Oversight

Section 328 of the National Defense Authorization Act (NDAA) for fiscal year 2010, established a formal requirement for the secretary of defense to submit:

... a comprehensive plan for improving the inventory management systems of the Military Department and the Defense Logistics Agency with the objective of reducing the acquisition and storage of secondary item inventory that is in excess to requirements. (ASD[L&MR], 2010, p. iii)

Therefore, all supporting agencies must align their efforts to reduce current inventory excess and potential future excess. This alignment for Acquisition Category (ACAT) I and II programs/weapon systems must be managed in coordination with the respective program manager (PM).

Under guidance of the Defense Acquisition System (DAS), a PM is the designated individual with responsibility for and authority to accomplish program objectives for development, production, and sustainment to meet the user’s operational needs. The PM is accountable for credible cost, schedule, and performance reporting to the Milestone Decision Authority (MDA).

Another requirement for PMs managing Acquisition Category (ACAT) I and II programs is to adopt acquisition strategies that provide for the technical data rights needed to sustain systems and subsystems over the life cycle and acquire or retain rights to technical data in accordance with the program manager's data management strategy regardless of the planned sustainment approach [USD(AT&L)], 2003).

3. Life-Cycle Sustainment Plan

The program manager's plan for formulating, implementing, and executing the sustainment strategy, and part of the overall acquisition strategy is the Life-Cycle Sustainment Plan (LCSP) (USD[AT&L], 2003). The LCSP is a living document written during the planning/concept phase which provides logistics support requirements (spare parts) to be acquired, produced, delivered, and phased-out with an integrated schedule for the weapon system. The LCSP also provides for the logistics support infrastructure to be produced by activity and time frame.

An acquisition strategy is a plan that serves as a roadmap for program execution from program initiation through post-production support. It is the framework for planning, directing, contracting for, and managing a program. For each ACAT program, the acquisition strategy must be documented and must address all topics required by DOD 5000.2-R. DOD 5000.2 Section 4.7.3 and 5000.2-R, Part 2.1 provide detailed instructions. Additionally, the Acquisition Life-Cycle Support Plan (ALSP) guide, 2003, provide additional guidance,

The acquisition strategy must be a stand-alone, single purpose document, or it may be included in a more comprehensive, multi-purpose document (e.g., a Navy Master Acquisition Program Plan (MAPP) or an Air Force Single Acquisition Management Plan (SAMP). The PM develops the acquisition strategy in preparation for program initiation, prior to a program initiation decision, and updates it prior to all major program decision points, whenever the approved acquisition strategy changes or as the system elements become better defined.

- Identify the planned acquisition strategy from the Acquisition Plan.
- Describe the general philosophy and specific acquisition strategies employed. Explain how they were selected, including the

determination that the acquisition is a new development or commercial item.

- Include the evolving contractual approaches and incentives for Life-Cycle Cost (LCC), Reliability and Maintainability (R&M) and supportability goals. For example, at Milestone A, explain why an existing U.S. allied Military, commercial, or product improvement of an existing end item, was not selected over a proposed new end item.
- Discuss how the AL program will implement the initiatives of acquisition reform to accommodate streamlining and tailoring recommendations received from industry.
- Identify which subsystems, components, or materials require new or additional development.
- Identify any existing military or commercial components that will be evaluated for use or possible modification during the next phase.
- Explain and provide reasons for urgency or other special delivery requirements if it results in concurrency of development and production constitutes justification for not providing for full and open competition.
 - For example, timely delivery might be required in order for the Government to meet its obligations under another contract; or if timely delivery or performance is unusually important to the Government, liquidated damage considerations might be required. (pp. 28–29)

In summary, this chapter uncovered that the DOD's standards for stock retention limits lack goal congruence with each of the service components' retention policies. The six economic retention studies provide valuable recommendations which are synchronized with the DOD's stock retention policy. And finally, the U.S. Navy's LCI retention methodology policy can be optimized if its coupled with a weapon systems' life cycle sustainment plan.

IV. METHODOLOGY AND ANALYSIS

A. METHODOLOGY

1. Methodology Introduction

This chapter describes the methodology utilized in this study, and offers intuition on the applied analysis classification. Specifically, it addresses the following questions:

- How was the research design selected, and why?
- How were the methods selected for analysis, and why?
- How was the data collected and organized?
- What is the value of down selecting the research object and scope to the CH-53E Heavy Transport Helicopter ?

The outcome of this research is valid as long as the methodology used to collect, evaluate, and analyze the data is congruent with its prevailing ontologies.

Ontology in this context refers to the character of the world as it actually is and the fundamental assumptions we make about the nature of the causal relationship among governing policies, the “spirit” of, and implementation of these policies (Hall, 2003, p. 374).

This research makes three key assumptions as follows:

- All governing policies published by the secretary of defense are adhered to in accordance with the meaning provided and no other.
- There is no causative explanation that would prevent a service component to refrain from carrying out the law-like intent provided by the instructions differently than its intended implementation across space and time.
- Inventory is contingent upon the implementation (efficiently or inefficiently) of governing instructions.

The research design follows a linear exploration from the source, to interpretation, implementation, and ultimately, consequences for inventory policies in effect.

2. Scope of Research

The scope of this project is concentrated on the reparable aeronautical components assigned for the CH-53E heavy transport helicopter (aviation weapon system) wholesale level. The CH53E aircraft selected as the research object because of the ease of access to maintenance, demand, and reliability data, as well as the aviation platform's mature state in the inventory system. The main objective of this research is to validate *acquisition advice codes and equipment operational capabilities code* as an integral factor for the life cycle indicator (LCI) retention methodology.

3. Literature Review Summary

Altogether, 46 different documents were reviewed for this research project. The secretary of defense's DOD Instructions include detailed and prescriptive directions into the conduct of an economic analysis. Component services' instructions for service retention limits were not in conflict with DOD instructions. However, the automated methods used in ERP limits do not fully complement the intent, purpose, and outcome of an economic analysis. Specifically for the CH53 heavy lift helicopter, aeronautical components are stratified by LCI methodologies, but there was no evidence in the literature to suggest that the LCI as a single parameter meets the economic analysis criteria identified in DODI 4140.1-R instruction (ODUSD[L&MR], 2003). LCI methodology does however, attempts to bridge the life-cycle cost of the aircraft into a time horizon category.

The Life Cycle Sustainment Plan (LCSP) for aeronautical weapon systems documents the Program Manager and Product Support Manager's plan for formulating, implementing and executing the sustainment strategy, and is part of the overall Acquisition Strategy of a program. (DAU, 2014) The LCSP bridges the acquisition and maintenance plan for the weapon system in support of life cycle cost and total ownership cost.

The CH53 aircraft is an aeronautical weapon system. As such, the LCI stratification methodology may slightly differ among its type model series (i.e., CH53D, CH53E, and CH53K). However, if the LCI is applied to the individual sub-systems with

exclusion for certain types of acquisition advise codes, then the quantity retained would be considerably greater and the impact less substantial.

4. Hypothesis/Research Question

The general research question for this thesis is as follows: Are service retention limits (SRLs) improved by enhancing Life Cycle Indicators (LCI) custom parameters with additional custom parameters?

H_0 = Null Hypothesis = Life Cycle Indicators are the optimal custom parameter to calculate SRLs.

H_A = Alternative Hypothesis = Life Cycle Indicators are not the optimal custom parameter to calculate SRLs.

The following are specific questions for research objectives are:

- Economic retention quantity (ceilings and floors)
 - Is the SRL by LCI the optimal approach to establish ceilings and floors for economic retention quantities?
- Contingency retention (ceilings and floors)
 - Is contingency retention stock management driven [qualitative] vice model driven [quantitative] the best retention alternative?
- Logic for life-cycle driven retention
 - What are the most important factors to include for life-cycle driven retention?
- Risk to be incurred by adopting recommendations
 - What is the primary risk associated with accepting the alternative hypothesis?

5. Underlying Concept for Retention

Stratify stock above the AAO level as ERS if it is more economical to retain than to dispose and then potentially repurchase. According to DODI 4140 (Volume 6):

To warrant economic retention, an item will have a reasonably predictable demand rate. If the expected demand for an item is probable but not predictable, the item may be considered as ERS provided the managing DOD component has documented rationale that economically justifies

retention and is available for audit purposes. (DODI 4140 (Volume 6) 2014, p. 15)

The U.S. Navy's inventory retention policy is based on a weapon system acquisition-life-cycle. A weapon system is ascending, steady (mature), or declining. In practice, they extend this philosophy to the weapons' sub-systems and calculate ERS accordingly. See Appendix B.

System retention limits by life cycle indicators provide a systematic inventory stratification that set a ceiling and floor based on whether the system is ascending, mature, or declining in its life-cycle profile. Refer to Appendix B for a comprehensive review of the economic retention quantity calculation. Figure 13 illustrates the item mission essentiality codes alongside year-of-demand-based retention used in the ERQ quantity requirement in ERP. Table 3 illustrates the LCI retention methodology as it appears in the ERP functional design document:

Table 3. SRL by Life Cycle Indicators (from Gsell, 2014, p. 14)

LCI	IMECY	YDR	Minimum Retention
1	12	1.5	5
2	12	1.5	5
3	12	1.5	5
4	8	0	3
5	4	0	1

IMECY = Item Mission Essentiality Code Year
YDR = Year of Demand Based Retention

- Independent variable researched: life cycle indicators (LCIs)
- Dependent variables researched are the value of inventory and inactive inventory size (depth/range).

6. Methods of Analysis

This thesis analyses the LCI custom parameter against two additional custom parameters and reconciles the results against the dependent variables. Monte Carlo (MC) simulation is used to analyze the quantity of aeronautical components, and monetary

exposure due to the change of custom parameters. Table 4 illustrates the SRL retention results matrix as displayed in Chapter VII.

Table 4. Service Retention Limits (SRL) Results

	LCI (status quo)	LCI by component	LCI/AAC/EOC CBLR
INVENTORY VALUE \$\$\$			
RANGE OF NSN (QTY)			
DEPTH OF RANGE (QTY)			

The matrix in Figure 13 illustrates different types of considerations among the aircraft weapon system and the aeronautical component (sub-system).








Weapon System \ Aeronautical Component	Ascending	Mature	Descending
Ascending			
Mature		LCI + EOC	LCI + AAC + EOC
Descending		LCI + AAC	LCI + AAC + EOC
		LCI + AAC	

Figure 13. Weapon Systems and Aeronautical Components Matrix

7. Source of Data

The primary source of data for this project was N(3/4), NAVSUP Mechanicsburg, PA including the material key spreadsheet dated May 2014, along with the retention table data from the final stratification cycle (last completed stratification) dated March 2014. The secondary source of data was NAVAIR's PMA-261 Integrated Logistics Support Management System (ILSMS). ILSMS is a data repository that integrates 11 aviation factors and uses 10 years of historical baseline data to analyze aeronautical components.

ILSMS displays over 100 top-level metrics of actual data. Figure 14 is an excerpt of the data from NAVSUP (N 3/4) used for this research.

NIIN	COG	ICP Site Code	LRC	AAC	Replace Price	LRC Tech Ref Code	SYS_RET_LIMIT	MIN_RET	RETAIL_ALLOW	AAO (Reg)	ERQ	CRQ	FSA	AAOS	ERS	CRS
015329449	7R	P	XTB	V	1034997.00	XX	13.613	3	0	13.613	0	0	4.856	4.856	0	0
13163474	7R	P	XBK	C	\$165,611.00	XX	1517.101	3	347	1460.153	56.948	0	590.14	590.14	0	0
011258904	7R	P	XTA	C	\$6,963.00	XX	1228.903	3	149	1172.511	56.392	0	1107	1107	0	0
011522282	7R	P	XTA	V	489.95	XX	27.391	3	2	11.547	9.844	6	26.08	11.547	9.844	4.689
014591079	7R	P	XPB	C	\$18,499.69	ZP	1249.054	3	132	1121.606	127.448	0	357.369	357.369	0	0
013608223	7R	P	XTB	C	\$6,546.19	XX	1070.204	3	170	989.331	80.873	0	302.312	302.312	0	0
014290072	7R	P	XTC	C	\$2,678.59	XX	1209.228	3	546	948.752	260.476	0	629.841	629.841	0	0
011298384	7R	P	XTH	V	9685.89	XX	66	3	1	9.682	3.318	53	81	9.682	3.318	53
012755620	7R	P	XUS	V	31955.00	XX	7	3	0	7	0	0	3	3	0	0
007557169	7R	P	XTS	C	\$5,416.00	XX	972.578	3	169	923.893	48.685	0	458.3	458.3	0	0
010632830	7R	P	XTT	C	\$7,472.17	XX	968.959	3	139	902.925	66.034	0	247.024	247.024	0	0
014652541	7R	P	XTA	C	\$8,914.00	XX	783.109	3	137	682.121	100.988	0	421.067	421.067	0	0

POTENT_EXCESS	MIN_BUY_QTY	LOTOHOU	AAO_FCST	STRAT_PPR	STRAT_PPR_BYND	AAO_BACK	NSO_DELTA	STAT_SS	EOQ_LEVEL	REGENOIMD	ATTRITIONOIMD	PPV	LCI	FAM_GROUP
0	0	0	2.804	5	0	3	0	0.001	1.00	0.262	1.456	0	4	HCLB
0	0	0	909.731	6	0	0	0	0.001	0	159.224	38.197	0	4	COMB
0	0	0	950.13	0	0	0	0	0.001	0	61.354	12.026	0	4	
0	0	0	4.546	0	0	0	0	0.934	0	0.006	4.061	0	4	
0	0	0	772.856	0	0	0	0	0	0	180.975	35.775	0	4	HUUB
0	0	0	670.084	0	0	23	0	0.001	0	107.254	18.992	0	4	HMAH
0	0	0	295.751	3	0	4	0	9.84	0	12.392	77.769	0	4	HNGB
15	0	0	7.228	0	0	0	0	0.001	0	0.621	0.832	0	4	
0	0	0	0	0	0	7	0	0	0	0	0	0	4	
0	0	0	648.883	6	0	0	0	31.44	0	59.781	8.789	0	4	
0	0	0	686.888	0	0	7	0	0.001	0	57.504	12.532	0	4	BUGB
0	0	0	447.12	0	0	33	0	0.168	0	48.885	15.948	0	4	CV7B

Figure 14. NAVSUP N(3/4) Excerpt of Data Used in Thesis Analysis (Buhrman, 2014)

In summary, the methodology used for this research makes three distinct assumptions and has four research objectives. The assumptions and objectives are applied to the general research question: Are service retention limits (SRLs) improved by enhancing life cycle indicators (LCI) parameters with additional custom parameters? The data for this research was sourced from NAVSUP N 3/4 and PMA-261 ILSMS data repository.

B. ANALYSIS

1. Analysis Introduction

This section presents the analysis method, variable definitions, and the four logic scenarios utilized to discriminate economic retention quantities. The main research objective and hypothesis is that life cycle indicators provide the optimal custom parameter to calculate service retention limits (SRLs). However, according to the research results, the best alternative to a complete optimization overhaul to service retention limits was a refinement to current life cycle indicator (LCI) rationality.

WSS Philadelphia's inventory is an example of the current inventory growth problem. Data obtained from the DOD supply system inventory reports (SSIR) reflect an upswing trend for reparable aeronautical components during the past four years. Figure 16 illustrates two important observations: first, the increase quantity (depth) of inventory over time and second, the transposition of inventory quantities from ERS to CRS. Appendix H of this thesis provides the itemized information for inventory value used for Figure 15. Given the data collected from the SSIR, additional analysis is required to validate the same growth behavior in other inventory segments within NAVSUP.

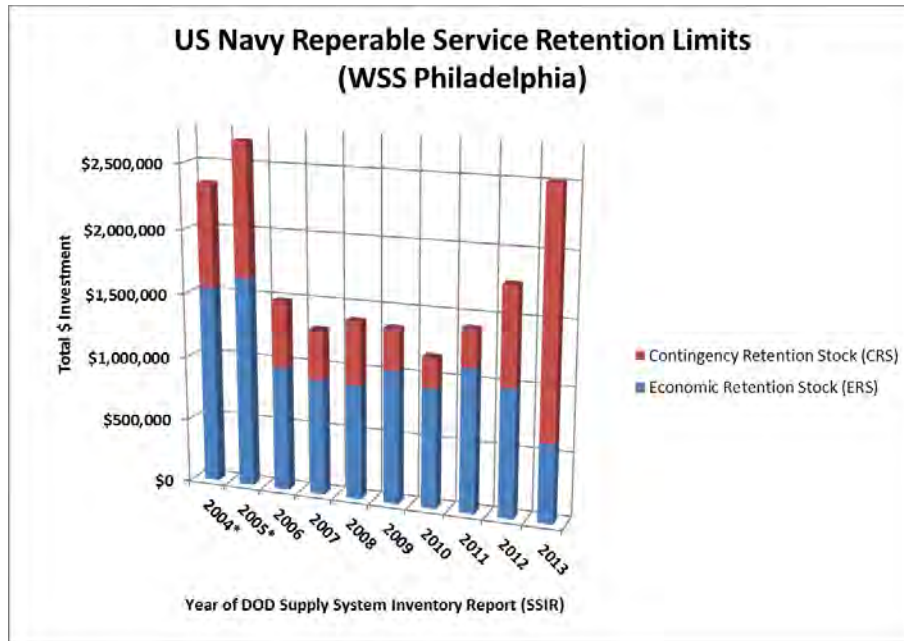


Figure 15. U.S. Navy WSS Philadelphia Reparable Service Retention Limits

2. Problem analysis

Thorough research of 46 documents and six different inventory assessments provide common denominators for inventory growth. The analysis discovered common denominators as the source for NAVSUP's inventory growth problem. The primary source for the inventory growth problem can be attributed to the dichotomy of life cycle indicators with acquisition advice code (AAC), and equipment operational capability codes (EOC). The basis for economic retention according to DOD I 4140.01 (Volume 6) is as follows:

To warrant economic retention, an item will have a reasonably predictable demand rate. If the expected demand for an item is probable but not predictable, the item may be considered as ERS provided the managing DOD component has documented rationale that economically justifies retention and is available for audit purposes. (ASD[L&MR]), 2014, p. 15)

3. Framing the Problem

Researchers have often referred to descriptive theory when framing a problem. Descriptive theory explains how and why our choices deviate from the normative model of expected utility theory. (Kahneman, Tversky, 1979). DODI 4140.01 Volume 6 while

still in effect has proven hard to implement because of its lack of specificity in quantifying the variables in the economic analysis. To properly frame the inventory growth problem, economic retention must meet three basic benchmarks: (a) No subsystem that qualifies for retention has been superseded by new components, (b) All subsystems are approved for installation on aircraft, and (c) NIINs and quantities recommended for retention have a quantifiable predictable demand rate in the near timeline horizon.

According to the ASD(L&MR) the current retention policy to retain aeronautical components after an economic analysis is the framework from which to filter new additions for economic retention:

Stratify stock above the AAO [approved acquisition objective] level as ERS if it is more economical to retain than to dispose and then potentially repurchase. To warrant economic retention, an item will have a reasonably predictable demand rate. If the expected demand for an item is probable but not predictable, the item may be considered as ERS, provided that the managing DOD component has documented rationale that economically justifies retention and is available for audit purposes. (ASD[L&MR], 2014, p. 15)

Today, there is a different approach for retention among economic and contingency quantities. According to Buhrman “Economic retention stock quantities are model driven while Contingency Retention Stocks are management driven” (2013, p. 4).

4. Inventory Stratification

NAVSUP’s inventory stratification depicted in Figure 16 provides for an efficient illustration of the SRLs. The AAO is the only funded segment in the SRL. As unfunded inventory segment, the economic and contingency retention quantities once exhausted from inventory are not replenished.

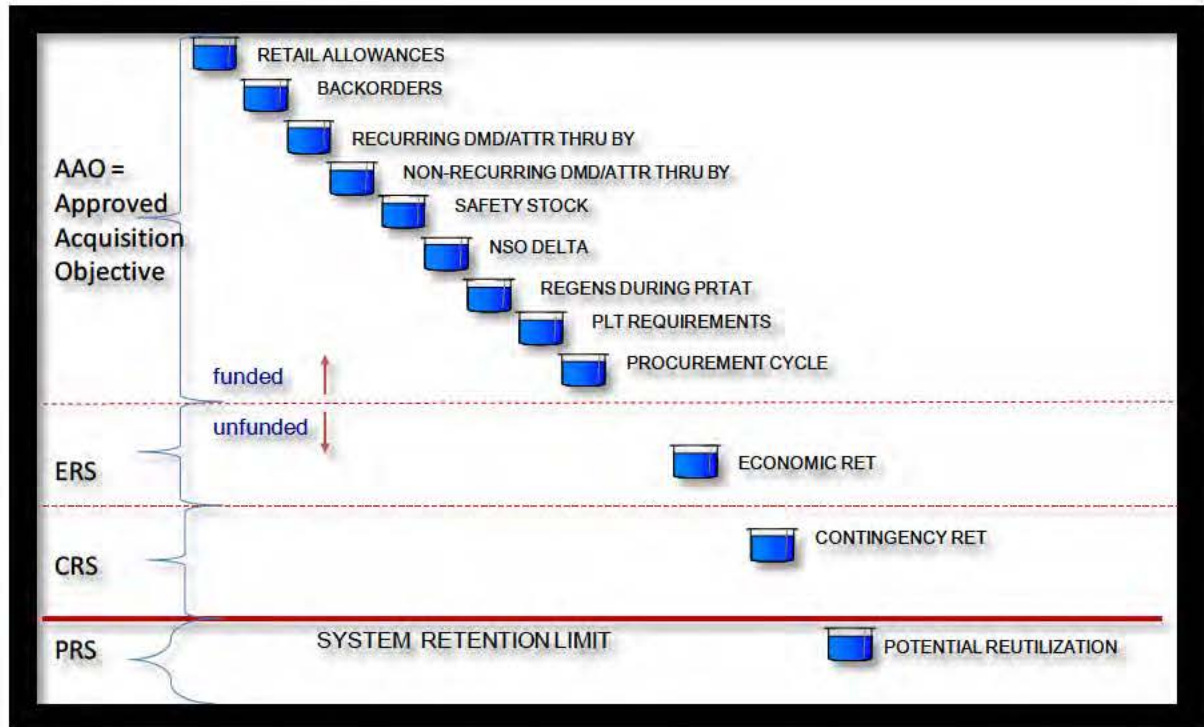


Figure 16. Stratification Buckets (from Buhrman, 2013, p. 4)

Figure 17 is a graphical representation of the mathematical logic used in ERP. The box labeled SRL-MIN is the focus of this research. The SRL MIN box list minimum requirement quantities (MRQs) for LCIs 3, 4, and 5. Today, LCI philosophy is the factor used to determine economic retention. Appendix B of this thesis provides a comprehensive explanation into the computation for economic retention quantities.

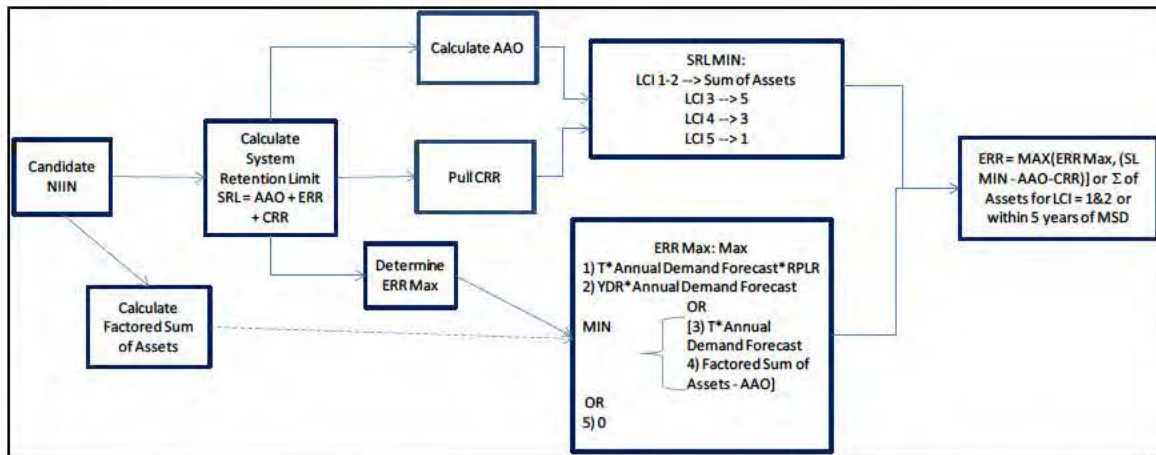


Figure 17. System Retention Logic Flow Chart (from Buhrman, 2013, p. 8)

The two inventory categories for spares exist; wholesale and retail. The wholesale segment provides replenishment to the retail segment. The retail segment supports the warfighter's mission during peace and wartime. The retail allowance also provides direct support to aircraft operational availability [Ao] and is tied directly to aircraft procurement navy (APN) 6 inventory funds. Materiel not categorized in the retail allowance exists to support depot maintenance and is managed under the navy working capital fund.

5. Condition-Based Logical Retention

Condition based logical retention (CBLR) introduced in this thesis refines LCI discrimination logic with two additional factors. First, CBLR considers the acquisition advice code (AAC) of the aeronautical component as an integral secondary factor to establish efficient retention decisions. A full list of AACs are recorded in Appendix E of this thesis. Second, CBLR considers the equipment operational capability (EOC) code as the tertiary required factor to establish efficient retention decision. A full list of EOC codes for the CH53E aircraft is recorded in Appendix F of this thesis.

6. CBLR Basic Definitions

- a) Service Retention Limits (SRL) is the quantity on hand and available to support weapon systems (wholesale & retail) $SRL = AAO + ERQ + CRQ$.
- b) Approved Acquisition Objective (AAO) is the approved & funded quantity available in wholesale and retail.

- c) Economic Retention Quantity (ERQ) is the unfunded retention quantity above AAO held with an expected probability of future demand [model driven].
- d) Contingency Retention Quantity (CRQ) is the unfunded retention quantity above AAO & ERQ with less than probable demand but held for contingency [management driven].
- e) Acquisition Advice Code (AAC) indicates how (as distinguished from where), and under what restrictions, an aeronautical component will be acquired.
- f) Life Cycle Indicators (LCI) is a three-digit code assigned to an aeronautical component based on the stage/life cycle and provides guidance for maximum and minimum quantities [ceilings/floors].
- g) Attrition Demand Quantity (ADQ) is the quarterly forecasted demand times the wear-out rate. The wear-out rate is the percentage of reparable items that fail, that is, items that through repair will not be returned to serviceable “A” condition.
- h) Regenerating Demand Quantity [REGEN] is the number of components repaired to “A” condition which offsets attrition demand quantity.
- i) Poisson-inverse quantity is the required quantity for a certain protection level [PL] within a specific period to protect against the expected number of failures during the same period [KλT].
- j) Equipment Operational Capability [EOC] is a one-digit code assigned to the subsystem of a weapon system. It indicates the impact to a weapon system if a subsystem becomes inoperable. EOC codes are published in the Mission Essential Subsystem Matrix (MESM) for respective aircraft.
- k) Minimum Required Quantity [MRQ] is the minimum quantity of aeronautical components required in the LCI matrix. (see Table 3).

7. CBLR Rationale

There are two basic assumptions dismissed under the life cycle indicators retention logic by CBLR: first, that all aeronautical components retained in economic retention are approved for installation on aircraft; second, that all aeronautical components in economic retention have a homogenous impact on aircraft.

Discriminating the LCI ERQ logic with the AAC/EOC matrix improves the quantity profile for inactive inventory. The new profile outcome provides greater value to a warfighter’s weapon system by weighing the impact on the aircraft and the supportability of the aeronautical component. The goal was to retain in ERQ approved

aeronautical components with the greatest value to the weapons system. Figure 18 illustrates the AAC/EOC numeric array decisions matrix with a differentiation scale.

Array "Value" Legend	0	Disposal Not Recommended
	0.190	
	0.200	Disposal with Reservation
	0.250	
	0.299	
	0.300	Disposal Neutral
	0.399	
	0.400	Disposal Recommended
	0.724	
	0.725	Disposal Highly Recommended
	1	

Figure 18. AAC/EOC Retention Disposal Matrix

In Figure 19, AAC codes and EOC codes are assigned a disposal value from 0 to 1 based on definitions for each code. Each respective value is equally weighted and given a disposal recommendation based on the retention disposal matrix listed in Figure 18. Appendix X and XI provide the definitions for acquisition advice codes and equipment operational capability codes respectively

(AAC) Array # 1	AAC Codes	Disposal Value	(EOC) Array # 2	EOC Codes	Disposal Value
	a	0.20		a	0.50
	b	0.30		b	0.10
	c	0.20		c	0.55
	d	0.40		d	0.30
	w	0.30		f	0.57
	h	0.40		g	0.95
	j	0.70		h	0.40
	l	0.70		i	0.60
	v	0.10		j	0.85
	y	1.00		k	0.45
	z	0.70		l	0.20
				z	0.05

Figure 19. AAC/EOC Value Array

8. CBLR Variable Definitions

The variable definitions listed in Table 5 provide definitions, formulas, and comments used for the CBLR model and augmented to the LCI logic. CBLR analysis

utilized Excel and validated the results through 30,000 trials simulated in Crystal Ball [Monte Carlo simulation program]. There were 986 National Item Identification Number [NIIINs] evaluated under the CBLR examining the size (depth)] and value of inventory.

The results for Scenario 1 and Scenario 2, are shown in Chapter VI of this thesis. There are two recommendations for aeronautical components with a 7R cognizance code.

Variable AC on Table 5 has two underlying assumptions: (1) If $RE > 0$, then funding was committed and a repair schedule was submitted to DOP or FRC. Planners only take such action when there is a probable expected demand in near time horizon (24 months), (2) If $RE > 33\%$, over failure rate AT, then the repair infrastructure for the component is deemed sustainable and self-sufficient. Table 5 provides the fundamental logic used in the analysis. More than definitions, it also includes the formula used and comments.

Table 5. Variable Definition for CBLR Discrimination

Variable	Definition	Formula	Comments						
S	Service Retention Limits	SRL = AAO+ERQ+CRQ	Qty from NAVSUP’s spreadsheet						
A	Approved Acquisition Objective	AAO = AAO Base + LOTOHObj	Qty from NAVSUP’s spreadsheet						
E	Economic Retention Quantity (Required) not applied	=MAX(SC1,SC2,SC3,SC4)	Greatest retention recommended for ERQ						
L1	Life Cycle Indicator # 5 with an MRQ = 1	N/A	N/A						
L3	Life Cycle Indicator # 4 with an MRQ = 3	N/A	N/A						
L5	Life Cycle Indicator # 3 with an MRQ = 5	N/A	N/A						
AT	Attrition Demand	N/A	Qty from NAVSUP’s spreadsheet						
RE	Regenerations = Repairs under lead time	N/A	From NAVSUP’s spreadsheet						
AS	Percentage of AAO from population NOT available for CBLR discrimination	=A/S	Used the qty provided from NAVSUP’s spreadsheet						
AQ	Quantity of population available for CBLR discrimination	=((1-AS)*S)	Used the qty provided from NAVSUP’s spreadsheet						
AC	Net quantity of aeronautical components repaired by designated overhaul point or fleet readiness center during period of interest	=(RE/AT)	Used the qty provided from NAVSUP’s spreadsheet						
PI	User-defined function utilized in excel workbook, and created by Professor Keebom Kang, GSBPP, Naval Postgraduate School. Provides the “required” quantity of components for an expected level of protection (.99), given the projected number of attritions (failures) during a given period.	=poisson_inverse(.99,AT)	Protection Level = 99% See Appendix I for user-defined function code						
AE	Not all aeronautical components have equivalent impact on aviation weapon system (EOC) nor they have the same life cycle of acquisition support (AAC).	=((AAC*.50)+(EOC*.50))	N/A						
OQ	Available quantity for discrimination “AQ” is filtered by “AE” value from the array.	=AQ*AE	N/A						
LX	ERQ requirements were sourced from original file. File assigned all 986 NIINs with	=IF(J15=4,E15*\$K\$5,IF(J15=5,E15*\$K\$4,IF(J15=6,0,IF(J15=3,E15*\$K\$5,0)))	<table><tr><td>LCI = 5 MRQ = 1</td><td>33%</td></tr><tr><td>LCI = 4 MRQ = 3</td><td>100%</td></tr><tr><td>LCI = 3 MRQ = 5</td><td>167%</td></tr></table>	LCI = 5 MRQ = 1	33%	LCI = 4 MRQ = 3	100%	LCI = 3 MRQ = 5	167%
LCI = 5 MRQ = 1	33%								
LCI = 4 MRQ = 3	100%								
LCI = 3 MRQ = 5	167%								

Variable	Definition	Formula	Comments
	LCI = 4. Given ERQ requirements, data was normalized for LCI 3 and 5 by implementing a ratio for MRQ to ERQ qty providing LCI = 4 = 100% of ERQ requirements qty.	$5 * \$K\$6, IF(J15=2, 999999999, IF(12=1, 999999999))))))$	
SC1	Scenario # 1: Most conservative discrimination logic with greatest retention quantity.	=IF AQ>0 and AC=0, then ERQ = Max(OQ, PI, LX)	N/A
SC2	Scenario # 2: Conservative discrimination logic with modest retention quantity.	=IF AQ>0 and AC<LX, then ERQ = Max(OQ, PI)	N/A
SC3	Scenario # 3: Normal discrimination logic with neutral retention quantity.	=IF AQ>0 and AC>LX, then ERQ = OQ	N/A
SC4	Scenario #4: Aggressive discrimination logic with least retention quantity.	=IF AQ>0 and AC>AQ, then ERQ = LX	N/A

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V. RESULTS OF SIMULATION

A. INTRODUCTION

This chapter describes the results for each of the two scenarios as well as the process used to filter repairable NIINs. To recap, Chapter IV, provided a clear description for the methodology and scope applied to this research. In addition, Chapter V, introduced condition based logical retention (CBLR) as an added discriminatory agent to LCI.

B. LIFE-CYCLE SUPPORT PLAN

The life cycle support plan (LCSP) is a living document written during the planning/concept phase that provides logistics support requirements (spare parts) to be acquired, produced, delivered, and phased out with an integrated schedule for the aviation weapon system. More important, the LCSP is the program manager's plan for formulating, implementing, and executing the sustainment strategy, and part of the overall acquisition strategy for each of its major subsystems. Therefore, independent assignment of life cycle indicators (LCIs) for each of the sub-systems provides for the greatest data fidelity, which is critical to ERQ requirements determination. The data received from NAVSUP N4 assigned LCI 4 to all NIINs. Perhaps the application of LCI 4 to all NIINs is not used when determining SRL retentions. However, LCIs 3, 4, & 5 are probably a better real-world representation for service retention limits calculations.

C. QUANTITY DETERMINATION FOR ANALYSIS

The 12th column of Figure 14, labeled [ERQ] represents the ERQ requirements for each NIIN when assigned LCI 4. The source of data provided required a normalization process to the ERQ requirement quantities when LCI 4 assignment was other than 4. For this research, the ERQ quantities were normalized by associating the ERQ quantities to the LCI minimum required quantity (MRQ) values.

For example, suppose NIIN 00-001-1234 under LCI 4 had an ERQ requirement quantity of 100. If during a simulation run, the NIIN was randomly assigned LCI 5, then

we assign the NIIN an ERQ of 33 (100 * 33 percent). Alternatively, if the NIIN is randomly assigned LCI 3, we assign the NIIN an ERQ of 167.

Figure 20 displays the framework utilized to normalized ERQ requirement quantities.

LCI = 5 MRQ = 1	33%
LCI = 4 MRQ = 3	100%
LCI = 3 MRQ = 5	167%

Figure 20. ERQ Requirements Quantity Normalization Matrix

The researchers acknowledge ERP may have computed a different ERQ requirement quantity under normal execution of ERP algorithms. However, given the information provided, this normalization approach removes assignment bias to ERQ quantities when LCIs are randomly assigned.

D. SCENARIO 1

The purpose of scenario 1 is to estimate the effect of employing more accurate LCI codes. We assume that actual values are evenly distributed among LCI = 3, 4, or 5, though we acknowledge the arbitrary nature of this assumption. We replicate 30,000 such random distributions and calculate the effect on our response variables. The results after simulating 30,000 iterations suggest no significant difference in quantity of components and value of inventory when compared to ERQ base requirements (status quo) under LCI 4. Figure 21 illustrates the comparative results for Scenario 1: average inventory value of \$452,809,326.

Status Quo (LCI = Same as Weapon System (Dependent))	
Status Quo	
Qty of Components in Inventory:	11,995
Value of Inventory	\$452,490,931.34

Scenario # 1	
LCI by Aeronautical Components (Independent of Weapon System)	
Qty of Components in Inventory: after 30,000 trials	11,995
Mean Value of Inventory: after 30,000 trials	\$453,044,305.00

Figure 21. Scenario # 1 Comparative Results

1. Crystal Ball Monte Carlo Simulation Results

Figure 22 illustrates that the mean inventory value after 30,000 simulated trials was \$453,044,905 with an estimated 99% probability the value would be no greater than \$575,888,870. In the unlikely event a trial falls in the 1% tail, the tail value at risk mean inventory value is \$587,323,431.

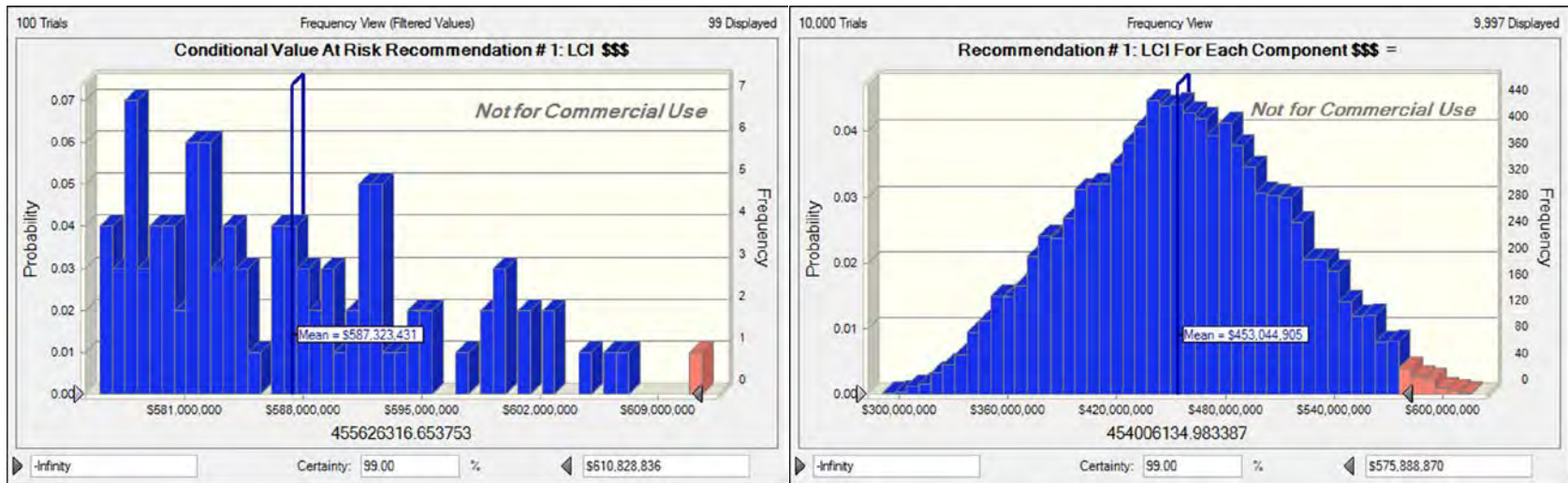


Figure 22. Scenario # 1 Inventory Value (\$\$) Results

Figure 23 illustrates that the mean inventory quantity after 30,000 simulated trials was 11,991 with an estimated 99% probability the value would be no greater than 13,435. In the unlikely event a trial falls in the 1% tail, the tail value at risk mean inventory quantity is 13,619.

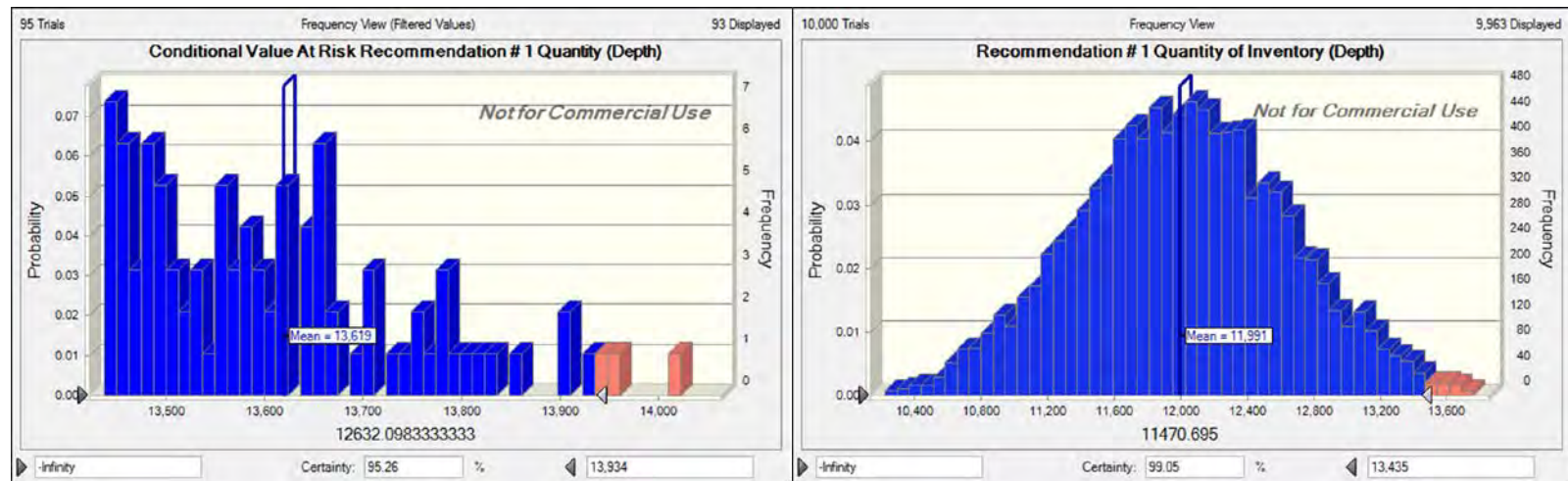


Figure 23. Scenario # 1 Inventory Quantity (Depth) Results

E. SCENARIO 2

The purpose of Scenario 2 is to estimate the impact of employing the CBLR methodology. We randomly assign LCIs, as in Scenario 1, but we implement the adjustments to ERQ quantities as per the CBLR. ERQ quantity requirements for each of the two scenarios were computed as a factor of LCI 4 quantity requirements. Under this scenario, the SC1, SC2, SC3, and SC4 logic from Table 5 identified the NIIN's condition quantity, and the greatest quantity among SC1, SC2, SC3, or SC4 was recommended as the economic retention quantity (ERQ): variable (E).

1. ERQ Quantity Requirements

The model and analysis for Scenario 2, computes ERQ quantity requirements in four separate calculations and selects the highest quantity as the quantity of interest to simulate. Table 4 of this thesis provides the variable definitions as well as the formulas used for computation. Variable definitions SC1, SC2, SC3, and SC4 are the four different considerations for an ERQ quantity requirement. Variable definition E was the quantity simulated in the Crystal Ball (Monte Carlo) program.

2. Results of Scenario 2

The results after simulating 30,000 iterations suggest a significant difference in quantity of components and value of inventory when compared against the ERQ base requirement (status quo) under LCI 4. ERQ required quantities decreased by 41% and the value of inventory decreased by 19% with an average inventory value of \$366,250,366. Figure 24 illustrates the results of Scenario 2.

Status Quo (LCI = Same as Weapon System (Dependent))	
Status Quo	
Qty of Components in Inventory:	11,995
Value of Inventory	\$452,490,931.34

Scenario # 2	
Weighted Average for LCI, AAC, EOC (Condition Based Logical Retention)	
Qty of Components in Inventory: after 30,000 trials	7,022
Mean Value of Inventory: after 30,000 trials	\$366,250,366.00

Figure 24. Scenario # 2 Comparative Results

3. Crystal Ball Monte Carlo Simulation Results

Figure 25 illustrates that the mean inventory value after 30,000 simulated trials was \$366,250,366 with an estimated 99% probability the value would be no greater than \$482,254,984. In the unlikely event a trial falls in the 1% tail, the tail value at risk mean inventory value is \$491,221,255.

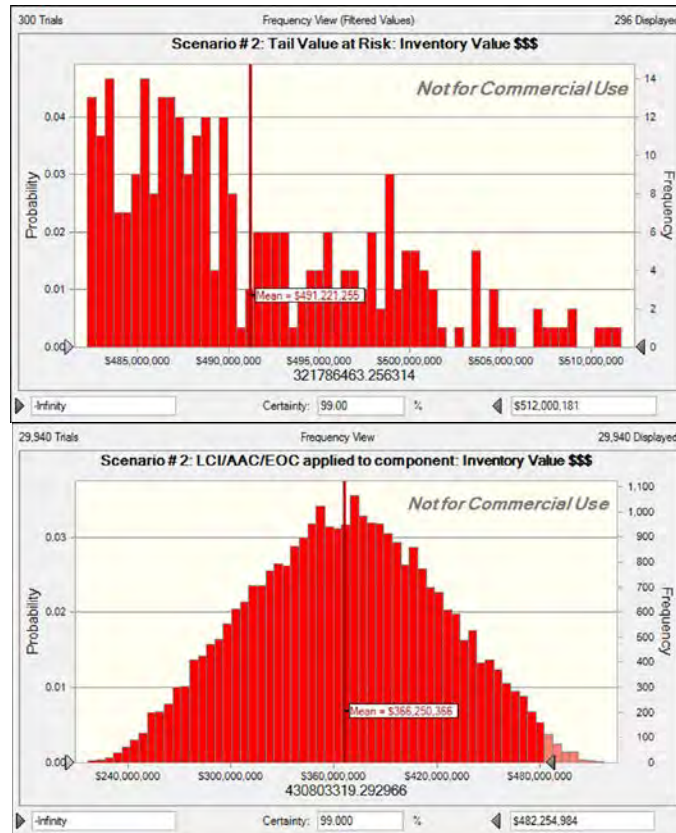


Figure 25. Scenario # 2 Inventory Value (\$\$) Results

Figure 26 illustrates that the mean inventory quantity after 30,000 simulated trials was 7,022 with an estimated 99% probability the value would be no greater than 7,364. In the unlikely event a trial falls in the 1% tail, the tail value at risk mean inventory quantity is 7,391.

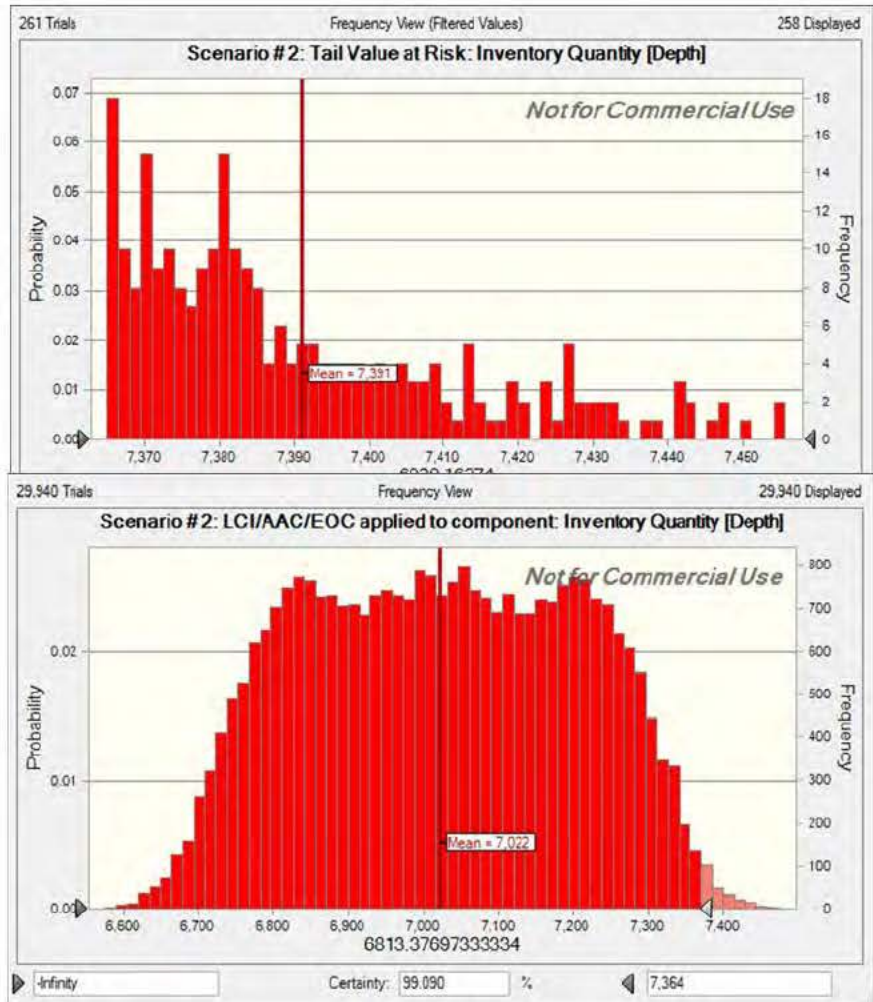


Figure 26. Scenario # 2 Inventory Quantity (depth) Results

VI. CONCLUSIONS AND RECOMMENDATIONS

1. Introduction

The goal of this project is to refine the service retention limits in a way that supports DODIs and DON policies. The approach taken by this project includes an in-depth study of over 46 documents and reports. This review finds that a portion of excess inventory qualified as inactive, has no value to the warfighter. However, there is evidence in the data analyzed in this thesis to support an effective benchmark for determining terminal aeronautical components in the inactive inventory. In addition, since there were only 986 NIINs in the data analyzed, there is a probability that there are additional terminal items on other segments of inventory.

This thesis addresses four research questions:

1. Is the service retention limits by LCI the optimal approach to establish ceilings and floors for economic retention quantities?
2. Is contingency retention stock management driven vice model driven the best retention alternative?
3. What are the most important factors to include for life-cycle driven retention?
4. What is the primary risk associated with accepting the alternative hypothesis?

2. Summary of Main Findings

In addressing research question one, this thesis finds the service retention limits by LCI as the optimal approach to establish maximum quantities (ceilings) and minimum quantities (floors) for each of its subsystems is currently subjected to an LCI equivalent to the CH53E weapon system: mature, LCI = 4.

An initial findings was the life cycle stage for each subsystems installed in the aircraft; while, the life cycle stage for the aircraft was mature, many of its sub systems were at different acquisition life cycle stages. The data analyzed contained 986 different NIINs of which 82% were NIINs centrally managed [mature-stage], 12% were NIINs classified as terminal items [declining-stage], 4% were NIINs classified as insurance

items, and 4% were NIINs classified as restricted. Each of the designated acquisition advice codes potentially reflect different applications for retention level as illustrated in Figure 11 of this thesis.

A secondary finding was that each subsystem was treated as having an equivalent impact on the weapon system. The data retrieved from ILSM and E-mail for the same range of NIINs, contained equipment operational capabilities [EOC] codes. EOC codes provide an additional layer of data fidelity for each NIIN. As outlined in the aircraft's mission essential subsystem matrix [MESM], the EOC codes specify the impact an aeronautical component has on the weapon system. Acquisition advice codes coupled with EOC codes contribute for a greater retention discriminator of aeronautical components. Refinements to the LCI mathematical model can improve retention decisions, logistics footprint, and value of inventory. Inventory simulation with randomly assigned LCIs [3, 4, & 5], and EOC codes resulted in a 41% quantity reduction and a 19% decrease in inventory value.

Although refinements described in this research provide a better alternative to current practices, service retention quantities are optimized by discriminating aeronautical components for either retention or disposal against cost avoidance for deferred repurchase actions. "Refocus the emphasis from a retention decision to a repurchase decision, given the main cost driver is the repurchase cost. For example, one change would be to change the section title from "Materiel Retention" to "Materiel Retention and Repurchase" (Pouy et al., 2007, p. 26)

The findings for the second research question show that contingency retention for this research was inconclusive. The qualitative approach for retention needs additional exploration and research. Although the past four years has observed a transposition of economic retention quantities to contingency retention quantities, the overall quantity of aeronautical components and value of inventory has increased. (See Figure 16) A comprehensive study should include retention constraints for material managers. The constraints can be factors such as logistics footprint (Lfp) as a measure of cube and weight and/or a percentage of ERQ population quantities and/or value of inventory.

These constraints can influence item managers to retain components with the greatest value to warfighter.

In addressing research question 3, this thesis finds the most important additive factors for life-cycle driven philosophy should be chosen with one purpose: to retain aeronautical components with greatest value to war fighter. Appendix E retention model developed by LMI provide additional factors to consider for service retention limits. The table represents a test conducted utilizing three distinct factors. 1. Condition of stock was categorized as serviceable (SS) or unserviceable (US). 2. Demand and condemnation. 3. Assignment by frequency: high frequency (HF) has a ceiling of 15 years, medium frequency has a ceiling of 20 years, and zero frequency has a ceiling of 15 units. When these factors were combined, the net savings in millions of dollars was substantial. Considering, these factors as additive to the LCI philosophy can improve in the discrimination process for retention.

The findings for the fourth research question show the risks associated with accepting the alternative hypothesis is low for the repurchase of an aeronautical component that has been previously disposed of. Given, that the risk is initially mitigated by disposing aeronautical components that meet certain acquisition advice code criteria and have low impact on the aircraft weapon system. Conclusion: *“Life Cycle Indicators by themselves are not the optimal custom parameter to calculate Service Retention Limits (SRL) for the inactive inventory.”*

Table 6 provides a summary of the main findings for each of the research questions addressed in this thesis.

Table 6. Primer for Research Questions

Research Question	YES	NO	INCONCLUSIVE
Are service retention limits (SRL) improved by enhancing Life Cycle Indicators (LCI) custom parameter with additional custom parameters?	X		
Is the service retention limit by LCI the optimal approach to establish ceilings and floors for economic retention quantities?		X	
Is contingency retention stock management driven [qualitative] vice model drive [quantitative] the best retention alternative?			X
What are the most important factors to include for life-cycle driven retention?	X		
What is the primary risk associated with accepting the alternative hypothesis?	X		

Figure 27 reveals the results of CBLR coupled with LCI retention policy. After 30,000 trials, a 19% decrease inventory value with a 41% decrease in the depth of quantities required for the CH53E reparable components in the inactive inventory.

	LCI = 4 (status quo)	LCI/by Component	LCI/AAC/EOC CBLR
INVENTORY VALUE \$\$\$	\$452,490,931	\$452,809,326	\$366,250,366
RANGE OF NSN (QTY)	986	986	986
DEPTH OF RANGE (QTY)	11,995	11,995	7,022

Figure 27. Results Matrix

3. Recommendations

Based on the main findings summarized above, here are the formulated recommendations.

- 1) Evaluate DODIs and DON policies every three years for adherence to three basic control processes (goal congruence). Goal congruence stipulates that: First, does each policy establishes a mutually supported standard(s) that is reasonably understood; second, is there evidence that performance is being measured against the standards; and third, there is a conduit for correcting deviations from standards and plans (Koontz, O'Donnell, & Weichrich, 1980).
- 2) Economic analyses are conducted in strict adherence to DOD instruction 7041.3 enclosure (3) with consideration to salvage rate, holding cost, mean acquisition price, discount factor, and time line horizon for aeronautical components. In addition, a self-evaluating metric is developed to assess how effective is the economic analyses avoiding repurchase cost of aeronautical components.
- 3) Re-name economic order quantity (EOQ) to represent an additional layer of stock in ERP. Appendix A section e, provides the calculation used in ERP. The economic order quantity calculation definition in ERP is not the optimum quantity (Q^*) referred universally. The economic order quantity (EOQ) as defined by Harris, and later by Wilson, is a quantity designed to optimally tradeoff economies of scale (order costs including opportunity cost). (Doerr, 2014).

- 4) Partnership with the Naval Postgraduate School's Graduate School of Operations and Informational Sciences (GSIOS) to optimize mathematically service retention limits currently used in ERP.
- 5) Grant potential excess exclusion to NIINs or family group codes vice a blanket inclusion to all subsystems in the weapon systems.

4. Overall Conclusion

LCI retention policy can be refined by independently assign LCIs to aeronautical components and coupling the LCIs with the newly developed *condition based logical retention* described in this thesis. The U.S. Navy will have in its inactive inventory a pool of aeronautical components that have the greatest value for an aircraft weapon system. Future research should consider *cost avoidance* of having to repurchase a previously disposed asset as a factor for economic retention in its mathematical model.

APPENDIX A. NAVY'S NWCF-SM WHOLESALE STOCK RETENTION CALCULATION

A. SRL CALCULATION STEPS

SRL for each item is the result of first calculating a preliminary SRL, then applying item life-cycle ceiling and floor parameters. The preliminary SRL is the sum of AAO and ERQ and is constrained by ceiling and floor thresholds in accordance with the item life-cycle indicator. CRQ is then added to the preliminary SRL to arrive at the final SRL for an item.

Preparing to Calculate System Retention Limit Calculation, ICP Managed Assets
(LRC Site Code = 'M' or 'P')

$$\text{SRL} = \text{AAO} + \text{ERQ} + \text{CRQ}$$

Where:

AAO = Approved Acquisition Objective, as calculated in A, below

ERQ = Economic Retention Quantity, as calculated in B, below

CRQ = Contingency Retention Quantity, as retrieved in C, below

Compute Approved Acquisition Objective (AAO)

$$\text{AAO} = \text{AAO Base} + \text{Life of Type OH Objective (LOTOHObj)}$$

$$\begin{aligned} \text{AAO Base} = & (\text{Retail Allowances}) + (\text{Backorders}) + (\text{PPR's through Strat Horizon}) \\ & + (\text{PPR's one PCLT beyond end of Strat Horizon}) + (\text{Dmd Fcst through Strat Horizon}) + \\ & (\text{SafetyStock}) + (\text{NSO Delta}) + (\text{RegenDmd}) + (\text{AttritionDmd}) + (\text{EOQ Level}) \end{aligned}$$

b. Item life-cycle ceilings and floors. Item life-cycles and the respective values for ceilings and floors are shown below.

Life-Cycle Driven Retention Ceilings and Floors

Life Cycle Indicator	Determining Date	Phase	Retention Ceiling Years of Demand	Minimum System Retention Floor
1	Item Entry Date	Initial Operational Capability (IOC)	12	Sum of all Assets
2	Item Entry Date	Pre-MSD	12	Sum of all Assets
3	Material Support Date	Demand Development Interval (DDI)	12	5
4	DDI End Date	Mature	8	3
5	Date IRD Established	Sunset	4	1
6	Item Retirement Date	Retirement	0	0

c. Ceilings. The ceiling applied to the preliminary SRL is calculated on a basis of demand over a time period. ERQ is then derived as the balance of ceiling years minus AAO. Thus, ERQ is only applied up to the limit of the retention ceiling. This method uses AAO to build towards the ceiling threshold and minimizes the ERQ needed to achieve the ceiling quantity.

d. Floors. The floor for item retention is set as an asset quantity. The floor is applied to overall SRL so minimum assets specified by the floor for that life-cycle phase are retained, even if there is no AAO.

e. The ceiling and floor thresholds ensure more assets are retained in early life-cycle phases and prevent disposal of our last assets, even in the later sunset life-cycle phase.

f. Early life-cycle protection. There is no disposal consideration for items assigned a life-cycle indicator of 1 or 2, or if the Material Support Date is less than 5 years in the past.

2. Components of the SRL Calculation. The components of SRL calculation are described below.

B. APPROVED ACQUISITION OBJECTIVE

AAO is the first component of the SRL calculation and represents anticipated requirements. Determination of the AAO is based upon the requirements to be funded for an item and accounts for the Life-of-Type-On-Hand-Objective.

Approve Acquisition Objective (AAO) Computation

AAO = AAO Base + Life of Type OH Objective

AAO Base =

	1: Retail Allowances
Plus +	2: Backorders
Plus +	3: PPRs through Strat Horizon
Plus +	4: Planned Programed Requirement (PPRs) through Strat Horizon
Plus +	5: PPRs one Procurement Lead Time (PCLT) beyond end of Strat Horizon
Plus +	6: Demand Forecast through Strat Horizon
Plus +	7: Safety Stock
Plus +	8: NSO Delta
Plus +	9: RegenDMD
Plus +	10: Attrition Demand
Plus +	11: EOQ level

AAO Base =

C. ECONOMIC RETENTION QUANTITY

Per the SRL calculation explanation above, ERQ calculation will be constrained to a maximum value by the ceiling, and set to a minimum value by the floor. (2) To accommodate multiple scenarios which can indicate a need to retain material, ERQ is considered using four methods. Those four methods are then compared and the highest value is selected as the ERQ. ERQ will equal the greater of the following methods:

(a) Calculate ERQ as the balance of ceiling years beyond AAO times annual attrition demand. This method considers the life cycle of the item and the attrition of the item.

(b) For items with a life-cycle indicator of 1–3, calculate ERQ as 1.5 times annual demand forecast. This method considers early life-cycle items which do not have high attrition and creates an ERQ option based on one and one half (1½) years of annual demand. The years of demand retention parameter is configurable in ERP.

(3) Calculate ERQ as the lesser of the balance of ceiling years beyond AAO, times annual demand; or the sum of factored on hand assets (excluding “F” condition), minus AAO.

This method considers the life cycle of the item and demand of the item as well as the number of expected RFI assets not earmarked for requirements. As such, it provides retention emphasis to assets other than “F” condition and addresses cases where there is low attrition, but high demand.

(4) Calculate ERQ as the minimum system retention floor quantity minus AAO. Because it is possible for the previous methods to provide a result of zero, this method ensures some assets will be retained for items in life cycles 3–5 and all assets will be retained for items in life cycles 1 and 2.

Note: The sum of the AAO and ERQ will comprise the preliminary system retention limit. The CRQ will be a direct additive to this and complete the calculation of the final system retention limit.

D. CONTINGENCY RETENTION QUANTITY

The third component to wholesale retention levels is the CRQ, which is the extra level of protection over and above AAO and ERQ needed to minimize risk to stakeholders. CRQ is utilized by the cognizant WSS Planner or FMS personnel to account for factors not covered by existing requirements and economic based retention.

Establishment of CRQ is dependent on effective collaboration with HSC, PEO, and fleet stakeholders to ensure proper retention quantities.

(1) Definition. The official DOD definition relates that CRQ represents anticipated DOD demand not currently reflected in the requirements; items used primarily in war time which have limited use in peace time; e.g., mine sweeping material, or material held for future FMS.

(2) Applying CRQ. CRQ is a DOD approved inventory category which can be used to retain material based on requirements not covered by demand, or as identified by collaboration with external stakeholders. Recording as CRQ prevents material from stratifying as PRS and thus prevents disposal.

(3) Contingency types. Contingency retention material provides a contingency benefit that supports its retention. The following are types of contingency retention:

- (a) Reclamation and Cannibalization,
- (b) Potential FMS,
- (c) Humanitarian assistance and disaster relief,
- (d) Military Operational Necessity,
- (e) Diminishing Manufacturing Sources (DMS) and Material Shortages, and
- (f) Weapon System Exclusion.

(4) CRQ identification. CRQ is identified using the following two methods. First, NAVSUP WSS planners may identify CRQ via inventory review. Second, CRQ can be identified by external stakeholders via weapon system exclusion or item level request.

(5) Recording CRQ. CRQ, generated outside potential excess reviews, is established to protect approved quantities for an approved duration. CRQ is accomplished through the use of a Z301 sales quote transaction in Navy ERP.

(6) Recording duration. During potential excess reviews, to retain material for CRQ purposes, NAVSUP WSS assigns action reason codes in ERP for the applicable assets. Action reason codes for CRQ generate Z301 sales quotes in ERP which prevent disposal and categorize material as retained for contingency. NAVSUP WSS uses a unique action reason code for contingency retention requirement resulting from stakeholder request. CRQ, generated in this manner, remains active for 9 months, protecting the requirement through the Financial and Logistics Integrated Requirements Report (FLIRR) cycle and the subsequent semi-annual FLIRR cycle. CRQ is therefore revalidated annually. Z301 sales quotes are input for weapon system exclusion items, as well individual items as the retention decision is re-validated.

(7) CRQ collaboration. NAVSUP WSS collaborates with HSC, PEO, and Fleet stakeholders to identify CR based on weapon system exclusion and item-level planned disposal actions.

NAVSUP WSS collaborates on CR in two phases – first in soliciting input on weapon systems for exclusion from disposal reviews, and secondly in providing stakeholders with the opportunity to review planned disposals.

(8) CRQ review. NAVSUP WSS reviews CR as part of the comprehensive PRS review during each disposal review cycle and in accordance with the steps in paragraphs 7.a. and 7.b. of NAVSUPINST 4500.13A. This includes NAVSUP N3/4 approval of weapon system exclusions, and a NAVSUP WSS hierarchical management review by dollar value for any non-exempted items or systems.

(9) CRQ validation. Commander, NAVSUP WSS will attest in writing to the validity of CR decisions for each review cycle.

(10) FMS. FMS CRQ requirements will be composed of two parts, historical demand and program based. FMS CRQ Z301 sales quotes will be input for quantities of less than or equal to the quantity on-hand based on the following criteria:

(11) CRQ management. Z301 sales quotes are date driven. New Z301 sales quotes can be added with new dates as requirements arise. (*NAVSUP instruction 4500.13A retention and reutilization of material assets*.2013, p. E-2)

E. ECONOMIC ORDER QUANTITY CALCULATION

The Economic Order Quantity (EOQ) as defined by Harris, and later by Wilson, was a quantity designed to optimally tradeoff economies of scale (order costs that can be amortized) with the variable time-dependent costs of inventory (holding costs including opportunity cost) (Doerr, 2014).

EOQ Level Definition

EOQ Level = the additional quantity of material (above and beyond the "theoretical pipeline") recommended by the "buy/repair plan" to be purchased in order to meet future demand.

If the "buy/repair plan" has recommended no "new procurement initiations" EOQ level is set to 0.

Else,

EOQ Level = ('Factored Sum of Assets Plus' + 'Procurement on Order') - 'Theoretical Pipeline'

New Procurements Initiations = any new, unfixed / unreleased purchase request for procurement that have been recommended by the "buy/repair plan" and have a delivery date that falls before STRAT Horizon (24 months) plus one procurement lead time beyond STRAT Horizon.
**Means that purchase request would need to be initiated prior to the end of the STRAT horizon.

Procurements on Order = the sum of all procurements purchase orders in the system as of the date that retention limit is run plus the sum of all firmed/fixed procurements in the system as of the date the retention limit is run.

Theoretical Pipeline =

	1: Retail Allowances
Plus +	2: Backorders
Plus +	3: Demand Forecast (24 months)
Plus +	4: Planned Program Requirements (PPRs) 24 months
Plus +	5: Safety Stock
Plus +	6: NSO Delta
Plus +	7: Fixed Requirements with 99000 Reason Code
Plus +	8: Regeneration Demand
Plus +	9: Attrition Demand
Plus +	10: PPRs with RDD between end of STRAT horizon (24 months) and one procurement lead time (PCLT) beyond end of strat horizon

Theoretical Pipeline =

Factored Sum of Assets Plus =

Definitions:

Factor Sum of Assets = The total of on-hand assets across all condition codes

Step # 1: Calculate **Factor Sum of Assets (FSA) Plus**

FSA Plus = Factored Sum of Assets (FSA) + Factored Due In Assets

Factored Due In Assets =

	1: Repairable Return though STRAT horizon (24 months)
	Sourced from DRP matrix 'method drp_matrix_recalc-order_repretfcst (= demandforecast * carcass return rate * survival rate)
Plus +	2: Release procurement purchase request (PRs) or Purchase orders (POs)
	Should NOT include repair PRs or Pos because those are already covered under the regular FSA
Plus +	3: Ready for Issue or Non-Ready for Issue components from other sources (MTIS) factored.
	Serviceable intransit
	Unserviceable intransit

Factored Due In Assets =

The EOQ depicted below and coded into ERP is not the “Optimum Quantity” (Q*) order quantity that minimizes total holding and ordering costs for the year.

Recommend EOQ in ERP be re-named to represent additional layer of stock.

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APPENDIX B. ECONOMIC RETENTION QUANTITY CALCULATION

ERQ calculations represent the optimal economic quantity to retain after considering factors such as re-procurement costs, storage costs, disposal/demilitarization costs, inflationary discount factors, and likelihood of future demand.

ERQ Calculation:

- Step #1 Compute "T"
T Optimum number of years of retention
T IEMCY - $[(\text{Procurement lead time in quarters} + 10)/4 + (\text{EOQ} / \text{Annual Demand Forecast})]$
**** If computation is less than 0, then use 0 ****

- Step #2 Compute Economic Retention Quantity
Select "Min Value" of
T * Annual Demand Forecast
or
Factored Sum of Selected - AAO

****Factored sum of selected assets excludes "F" condition assets.**

- Step #3 Select "Max Value" of
Step #2 "selection"
or
YDR * Annual Demand Forecast
or
T * Attrition Demand

**** If computation is less than 0, then use 0 ****

- Step #4 Compute ERQ with LCIs "1 & 2"

- 4a If LCI is 1 or 2 then, ERQ = sum of all assets (protect all assets)
4b If Item Entry Date is less than "<" five (5) years, then ERQ = sum of all assets (protect all assets)
4c Apply steps "4a & 4b" across all condition codes to raw quantities for the component being reviewed.

Formula "IF (MAX (Raw Quantities, (AAO + ERQ_{calculated}), MRQ) Raw Quantities, set ERQ Raw Quantities - AAO, else IF (MAX (Raw Quantities, (AAO + ERQ_{calculated}), MRQ) MRQ, set ERQ MRQ - AAO, else set ERQ ERQ_{calculated})

LCI "1 & 2" Formula Break Down:	
IF (MAX (Raw Quantities, (AAO + ERQ _{calculated}), MRQ) Raw Quantities, set ERQ Raw Quantities - AAO,	
Else	
IF (MAX (Raw Quantities, (AAO + ERQ _{calculated}), MRQ) MRQ, set ERQ MRQ - AAO, else set ERQ ERQ _{calculated})	

- Step #5 Compute ERQ with LCIs "3, 4, & 5"

IF(AAO + ERQ_{calculated}) < MRQ, set ERQ MRQ - AAO, else ERQ ERQ_{calculated}

- 5a LCI 3 MRQ 5 (see LCI table above)
IF(AAO + ERQ_{calculated}) < 5, set ERQ 5 - AAO, else ERQ ERQ_{calculated}

- 5b LCI 4 MRQ 3 (see LCI table above)
IF(AAO + ERQ_{calculated}) < 3, set ERQ 3 - AAO, else ERQ ERQ_{calculated}

- 5c LCI 5 MRQ 1 (see LCI table above)
IF(AAO + ERQ_{calculated}) < 1, set ERQ 1 - AAO, else ERQ ERQ_{calculated}

Definitions

- 1 Raw Quantities On Hand Un-factored Assets (across all condition codes)
- 2 ERQ_{calculated} Computation results from step #3
- 3 MRQ Minimum Retention Quantity (see LCI table below)
- 4 IEMCY Item Mission Essentiality Code Year "AKA Retention Ceiling Years of Demand"

Life Cycle Indicator	Determining Date	Phase	Retention Ceiling Years of Demand	Minimum System Retention Floor
1	Item Entry Date	Initial Operational Capability (IOC)	12	Sum of all Assets
2	Item Entry Date	Pre-MSD	12	Sum of all Assets
3	Material Support Date	Demand Development Interval (DDI)	12	5
4	DDI End Date	Mature	9	3
5	Date IRD Established	Sunset	4	1
6	Item Retirement Date	Retirement	0	0

APPENDIX C. LMI'S AVIATION RMC-R (ERL) DEPLETION TABLE BY MULTIPLE OF DEMAND AND YEAR

Table D-3. Depletion Probabilities—Aviation RMC-R by Multiple of Demand Forecast and Year

Multiple Year	1	2	3	4	5	6	7	8	9	10
1	0.294992	0.166044	0.121624	0.097800	0.081715	0.070789	0.061988	0.054173	0.048483	0.043703
2	0.151821	0.096682	0.081153	0.043551	0.033612	0.025721	0.023141	0.021093	0.018134	0.016464
3	0.092716	0.090061	0.088058	0.052428	0.041502	0.032853	0.025948	0.022534	0.020030	0.016768
4	0.070258	0.075493	0.068209	0.053945	0.044385	0.038316	0.030804	0.025341	0.023217	0.019879
5	0.043703	0.053642	0.053566	0.050379	0.039757	0.036115	0.030121	0.025873	0.022762	0.018816
6	0.023824	0.032473	0.037785	0.033536	0.032246	0.028452	0.025645	0.022003	0.017982	0.016692
7	0.021188	0.030501	0.031942	0.036039	0.034674	0.030501	0.028149	0.026631	0.024052	0.022838
8	0.017906	0.023596	0.026783	0.028880	0.029818	0.028073	0.028376	0.027162	0.022155	0.020637
9	0.014112	0.021396	0.023900	0.026252	0.026024	0.024583	0.025114	0.023900	0.022914	0.020334
10	0.009788	0.015023	0.017906	0.017602	0.021548	0.021548	0.019423	0.018209	0.019803	0.017527
11	0.007891	0.012443	0.014719	0.018285	0.016944	0.019575	0.017830	0.016388	0.014871	0.014847
12	0.006753	0.010243	0.012671	0.012898	0.013809	0.014871	0.014871	0.014340	0.013809	0.013278
13	0.000753	0.004119	0.013178	0.019137	0.021949	0.025189	0.022863	0.016178	0.012915	0.010833
14	0.000460	0.003027	0.011176	0.017290	0.020567	0.024427	0.022135	0.015512	0.012261	0.010239
15	0.000230	0.001514	0.005588	0.008645	0.010283	0.012213	0.011067	0.007756	0.006130	0.005120
16	0.000115	0.000757	0.002794	0.004323	0.005142	0.006107	0.005534	0.003878	0.003065	0.002560
17	0.000057	0.000378	0.001397	0.002181	0.002571	0.003053	0.002767	0.001939	0.001533	0.001280
18	0.000029	0.000189	0.000699	0.001081	0.001285	0.001527	0.001383	0.000970	0.000766	0.000640
19	0.000014	0.000095	0.000349	0.000540	0.000643	0.000763	0.000692	0.000485	0.000383	0.000320
20	0.000007	0.000047	0.000175	0.000270	0.000321	0.000382	0.000346	0.000242	0.000192	0.000160
Multiple Year	11	12	13	14	15	16	17	18	19	20
1	0.040744	0.038164	0.034750	0.031791	0.029742	0.028604	0.026835	0.025341	0.023672	0.022610
2	0.013885	0.012595	0.012291	0.011229	0.010395	0.009029	0.008118	0.007587	0.007132	0.007208
3	0.015478	0.012898	0.011229	0.010774	0.009560	0.008849	0.007891	0.006904	0.006525	0.006070
4	0.017906	0.017375	0.015630	0.013354	0.012519	0.011381	0.010091	0.009484	0.008953	0.007891
5	0.015706	0.013733	0.014264	0.013278	0.011077	0.010822	0.009408	0.008346	0.007863	0.007360
6	0.013961	0.013354	0.009256	0.009408	0.009332	0.008042	0.008877	0.007815	0.007284	0.006753
7	0.020713	0.017299	0.015478	0.012747	0.012443	0.011533	0.009863	0.010243	0.008270	0.007436
8	0.020789	0.018816	0.017375	0.016085	0.013961	0.014036	0.012822	0.011457	0.012215	0.011153
9	0.018968	0.018816	0.017678	0.016388	0.014795	0.013809	0.012291	0.012140	0.011457	0.010546
10	0.018920	0.014568	0.015326	0.013581	0.013885	0.013278	0.013278	0.012519	0.011229	0.010395
11	0.012974	0.013581	0.013885	0.013126	0.012291	0.011229	0.011002	0.010243	0.010698	0.011760
12	0.011077	0.012747	0.011305	0.012898	0.010850	0.010470	0.011229	0.009560	0.009408	0.008194
13	0.007271	0.008832	0.005590	0.006254	0.006224	0.006523	0.006853	0.006142	0.004470	0.004097
14	0.006702	0.008185	0.005124	0.005835	0.005861	0.006254	0.006662	0.005966	0.004223	0.002049
15	0.003351	0.004092	0.002562	0.002918	0.002931	0.003127	0.003331	0.002983	0.002111	0.001024
16	0.001675	0.002046	0.001281	0.001459	0.001465	0.001563	0.001666	0.001492	0.001056	0.000512
17	0.000838	0.001023	0.000640	0.000729	0.000733	0.000782	0.000833	0.000746	0.000528	0.000256
18	0.000419	0.000512	0.000320	0.000365	0.000366	0.000391	0.000416	0.000373	0.000264	0.000128
19	0.000209	0.000256	0.000160	0.000182	0.000183	0.000195	0.000208	0.000186	0.000132	0.000064
20	0.000105	0.000128	0.000080	0.000091	0.000092	0.000098	0.000104	0.000093	0.000066	0.000032

Figure 28. ERL Depletion Table by Multiple of Demand and Year (from Zimmerman et al., 2009, p. D-3)

APPENDIX D. ECONOMIC RETENTION STOCK ASSESSMENT CHECKLIST

Table. ERS Assessment Checklist	
Category	ERS Assessment Criteria
Future Demand	Is your procedure for identifying items with predictable demand credible, i.e., realistic and reliable?
	Is your procedure for identifying items with probable demand credible, documented, and available for audit?
Economic Analysis	Does your economic retention level (ERL) method quantify the maximum level of ERS based on a cost or savings trade-off?
	Are all of your assumptions documented and creditable?
	Is your final ERLs based strictly on economics?
	Is your quantification of significant costs and benefits in the ERL method documented?
	Does your ERL method discount future costs and benefits to account for the time value of money?
	Does the time horizon for your economic analysis align with the probability distribution for long term demand for your items?
	Does your ERL method provide for sensitivity testing to account for uncertainties in the future?
	Is your ERL method sufficiently documented?
	Are your ERS determinations based on ERLs that are derived from up-to-date and documented data sources?
Application	Does your application of the ERL analysis adhere to policy and, if grouping are applied, are they logical and not subjective?
	Do you apply your ERS determinations on a regular basis? Explain when you make your determinations (e.g., monthly, quarterly) and how you make your determinations (e.g., within your standard system, within a bolt-on to your standard system, outside your system).
Variables	Is the cost to store in your ERL method up-to-date and estimated with a high degree of confidence?
	Do you estimate the value of storage costs? If yes, explain how storage costs are calculated including data sources.
	Is the disposal return in your ERL method up-to-date and estimated with a high degree of confidence?
	Is the potential long-term demand in your ERL method up-to-date and estimated with a high degree of confidence?
	Are potential repurchase costs in your ERL method up-to-date and estimated with a high degree of confidence?
	Do you estimate the value of repurchase costs? If yes, explain how repurchase costs are calculated including data sources.
Weapon System Variables	Does your ERL method consider the remaining life of the system or item?
Reviews	Do you review and validate your ERL method at least annually?
	Do your logistics headquarters commanders or designees attest to the validity of their ERL methods in writing?
	Do you have on-going or periodic efforts to improve your long-term demand estimations?
	Do you have on-going or periodic efforts to improve your cost estimates?

Figure 29. Economic Retention Stock Assessment Checklist (from ASD[L&MR], 2014, p. 16)

APPENDIX E. RETENTION MODEL FOR REPARABLE COMPONENTS

Test	Different limits based on condition of stocks	Demand and condemnations	Assignments by frequencies	Net savings (in millions)
1	Yes SS = 20 years US = 10 years	No Just demand	No	-\$1,379
2	No All = 20 years	Yes Both used	No	-\$1,440
3	No All limits per frequency assignment	No Just demand	HF = 15 years MF = 20 years ZF = 15 units	-\$340
4	Yes SS = 20 years US = 10 years	Yes Both used	No	-\$1,455
5	Yes All limits per frequency assignment	No Just demand	SS HF = 15 years US HF = 8 years SS MF = 20 years US MF = 10 years SS ZF = 20-units US ZF = 10 units	-\$338
6	No All limits per frequency assignment	Yes Both used	HF = 15 years MF = 20 years ZF = 15 units	-\$197
7	Yes All limits per frequency assignment	Yes Both used	SS HF = 15 years US HF = 8 years SS MF = 20 years US MF = 10 years SS ZF = 20-units US ZF = 10 units	-\$235

Figure 30. Retention Model for Reparable Components (from Zimmerman, 2003, p. 4-7)

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APPENDIX F. ACQUISITION ADVICE CODES

NAVSUP P-485 Volume 2

1. GENERAL. An Acquisition Advice Code (AAC) is a single alphabetic character contained in card column (cc) 50 of the change notice. This code indicates how (as distinguished from where), and under what restrictions, an item will be acquired. The AAC will reflect applications of the three basic methods, i.e., by requisition, by fabrication or assembly, or by local purchase. The acquisition advice code is used for customer level, not system level, acquisitions.

Code	Explanation	Description
------	-------------	-------------

A	Service/Agency Issue, transfer, or shipment is controlled by authorities above the regulated ICP level to assure proper and equitable distribution. The use or stockage of the item requires release authority based on prior or concurrent justification. Requisitions will be submitted in accordance with agency or service requisitioning procedures.	
----------	---	--

B	ICP regulated Issue, transfer, or shipment is controlled by the ICP. The use or stockage of the item requires release authority based on prior or concurrent justification. Requisitions will be submitted in accordance with agency or requisitioning procedures.	
----------	--	--

C	Service/Agency Issue, transfer, or shipment is not subject to specialized controls regulated other than those imposed by individual service supply policy. The item is centrally managed, stocked, and issued. Requisitions will be submitted in accordance with service requisitioning procedures.	
----------	---	--

D	DOD integrated Issue, transfer, or shipment is not subject to specialized controls material managed, other than those imposed by the IMM or service supply policy. stocked and issued The item is centrally managed, stocked, and issued. Requisitions must contain fund citation and will be submitted in accordance with the IMM/services requisitioning procedures.	
----------	--	--

E Other service Issue, transfer, or shipment is not subject to specialized controls managed, stocked, other than those imposed by the service requisitioning policy. and issued The item is centrally managed, stocked, and issued. Requisitions may require a fund citation and will be submitted in accordance with the service requisitioning procedures.

F Fabricate or National stock numbered items fabricated or assembled from raw assemble materials and finished products as the normal method of support. Procurement and stockage of the items not justified because of low usage or peculiar installation factors. Distinctions between local or centralized fabricate or assemble capability are identified by the source of supply modifier in the “Source of Supply” column of the service management data lists.

G GSA or Veterans Identifies GSA or VA managed items available from GSA/VA Administration (VA) distribution facilities. Requisitions and fund citations will be Integrated Material submitted in accordance with GSA/VA/service requisitioning managed, stocked procedures. and issued

H Direct delivery Issue, transfer, or shipment is not subject to specialized controls under a central other than those imposed by IMM or service/agency supply contract policy. The item is centrally procured but not stocked. Issue is by direct shipment from the vendor to the user at the order of the ICP or IMM. Requisitions and fund citations will be submitted in accordance with IMM/service requisitioning procedures.

I Direct ordering Issue, transfer, or shipment is not subject to specialized controls from a central other than those imposed by IMM/ services supply policy. The contract/schedule item is covered by a centrally issued contractual document or by a multiple award Federal Supply Schedule which permits user activities to place orders directly on vendors for direct delivery to the user.

J Not stocked, IMM/service centrally managed but not stocked items. centrally procured Procurement will be initiated only after receipt of a requisition.

K Centrally stocked Main means of supply is local purchase. Item is stocked in for overseas only domestic supply system for those overseas activities unable to procure locally due to nonavailability of procurement sources or where local purchase is prohibited (e.g., DAR: Flow of Gold or by Internal military service restraints). Requisitions will be submitted by overseas activities in accordance with agency or service requisitioning procedures. CONUS activities will obtain supply support through local procurement procedures.

L Local purchase DLA/GSA/Service/Agency managed items authorized for local purchase, as a normal means of support, at base, post, camp, or station level. Item not stocked in wholesale distribution system of IMM/Service/Agency/ICP.

M Restricted Items (assemblies and/or component parts) which for lack of requisition specialized tools, test equipment, etc., can be used only by major major overhaul overhaul activities. Base, post, camp, or station activities will not requisition unless authorized to perform major overhaul function.

N Restricted Discontinued items no longer authorized for issue except on the requisition, disposal specific approval of the service inventory manager. Requisitions may be submitted in accordance with service requisitioning procedures in instances where valid requirements exist and replacing item data has not been furnished.

O Packaged fuels DLA managed and service regulated. Items will be centrally procured in accordance with DOD 4140.25-M but not stocked by IMM. Long lead-time required. Requirements will be satisfied by direct shipment to the user either from a vendor or from service assets at the order of the ICP or IMM. Requirements and/or requisitions will be submitted in accordance with service procedures.

P Restricted Indicates item is stocked or acquired only for SAP requirements, requisition Security or item is nonstocked and material is ordered from the contractor Assistance for shipment directly to the foreign government. Base, post, camp Program (SAP) or stations will not requisition.

Q Bulk petroleum DLA managed. Item may be either centrally stocked or available products by direct delivery under a central contract. Requirements will be

submitted by military services in accordance with IMM procedures. Item will be supplied in accordance with DOD 4140.25M.

R Restricted Indicates item is centrally procured and stocked as GFM in requisition GFM connection with the manufacture of military item. Base, post, camp, or stations will not requisition.

S Restricted For service managed items whereby the issue, transfer, or requisitioning, shipment is subject to specialized controls of the funding military other service service. Item is procured by a military service for the funding funded military service and is centrally managed by the funding service. The procuring military service has no requirement in its logistic system for the item.

T Condemned Item is no longer authorized for procurement, issue, use, or requisitioning.

U Lead Service As a minimum provides procurement, disposal, and single Managed submitter functions. Wholesale logistics responsibilities which are to be performed by the PICA in support of the SICA are defined by the SICA NIMSC code.

V Terminal item Identifies items in stock; but future procurement is not authorized. Requisitions may continue to be submitted until stocks are exhausted. Preferred items NSN is normally provided by the application of the phrase, “When exhausted use (NSN) .” Requisitions will be submitted in accordance with IMM/Service requisitioning procedures as applicable.

W Restricted Indicates stock number has been assigned to a generic item for requisition special use in bid invitations, allowance lists, etc., against which no instructions apply stocks are ever recorded. Requisitions will be submitted only in accordance with IMM/service requisitioning procedures. This code will be used, when applicable, in conjunction with phrase code “S,” “Stock as NSN’s .” It is considered applicable for use when a procurement source(s) becomes available. The phrase code “S” and the applicable “Stock as NSN’s “ will then be applied for use in stock, store, and issue actions.

X Semiactive item A potentially inactive NSN which must be retained in the supply no replacement system as an item of supply because stocks of the item are on hand or in use below the wholesale level and the NSN is cited in equipment authorization documents (TO&E, TA, TM, etc.) or in use assets are being reported. Items are authorized for central procurement but not authorized for stockage at wholesale level. Requisitions for “in use” replacement will be authorized in accordance with individual military service directives. Requisitions may be submitted as requirements generate. Repetitive demands may dictate an AAC change to permit wholesale stockage.

Y Terminal item Further identifies AAC “V” items on which wholesale stocks have been exhausted. Future procurement is not authorized. Requisitions will not be processed to the wholesale suppliers. Internal service requisitioning may be continued in accordance with service requisitioning policies.

Z Insurance/numeric Items which may be required occasionally or intermittently and stockage objective prudence requires that a nominal quantity of material be stocked item due to the essentiality or the lead time of the item. The items are centrally managed, stocked and issued. Requisitions will be submitted in accordance with IMM/service requisitioning procedures.

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APPENDIX G. CH53E MISSION ESSENTIAL SUBSYSTEM MATRIX



DEPARTMENT OF THE NAVY
COMMANDER NAVAL AIR FORCES
BOX 357051
SAN DIEGO, CALIFORNIA 92135-7051

5442
Ser N422C/ 1587
18 Nov 08

From: Commander, Naval Air Forces
To: Program Executive Officer, Air ASW Assault and
Special Mission Program (PMA-261)

Subj: CH-53E MISSION ESSENTIAL SUBSYSTEM MATRIX (MESM)
CHANGE

Ref: (a) Email CNAL Mr. Mike Soniak of 13 Nov 08 (NOTAL)
(b) OPNAVINST 5442.4M

Encl: (1) CH-53E MESM

1. In response to reference (a), subject proposed change to enclosure (1) is hereby approved, and may be used immediately.

2. Per reference (b), Mission Capability (MC) and Full Mission Capability (FMC) goals remain unchanged for CH-53E aircraft:

Mission Capable: 70% Full Mission Capable: 60%

3. COMNAVAIRFOR POC: LtCol Donald Scribner, (757) 445-7659 or DSN 564-7659.


JAMES COBELL, III
By direction

CH-53E
TYPE EQUIPMENT CODE: AHXD
MISSION ESSENTIAL SUBSYSTEM MATRIX (MESM)

Do not assign an EOC code if all equipment is operational. The aircraft is FMC.

Assign alpha character (C) of the EOC code when the following systems(s) are inoperative preventing the fleet/combat support mission. The aircraft is not capable of operating in a hostile environment, using weapons and countermeasures devices, or conducting secure voice communications. The aircraft is PMC, M or S.

AAQ-24(V) DIRECTED INFRARED COUNTERMEASURE SYSTEM	(NOTE 1)
APR-39 RADAR WARNING SET	(NOTE 1)
AAR-47 MISSILE WARNING SET	(NOTE 1)
ALE-47 CHAFF/FLARE DISPENSER	(NOTE 1)
ENGINE AIR PARTICLE SEPARATORS (EAPS) (DOORS AND BLOWERS)	
ICS (GUNNER STATION)	(NOTE 1)
IFF (ALL MODES)	
SECURE VOICE (KY-58)	(NOTE 1)
WEAPONS DELIVERY/ARMAMENT	(NOTE 2)

Assign alpha character (D) of the EOC code when the following system(s) are inoperative preventing the SAR/CASEVAC mission. The aircraft is not capable of conducting day and night SAR operations, CASEVAC of ambulatory and non-ambulatory evacuees, or using life support. The aircraft is PMC, M or S.

AC/DC POWER RECEPTACLE
LITTER SYSTEM

Assign alpha character (E) of the EOC code when the following system(s) are inoperative preventing the personnel transport mission. The aircraft is not capable of internal transport of personnel to and from landing areas, ship and shore. The aircraft is PMC, M or S.

LIFE RAFTS	
TROOP SEAT SYSTEM	(NOTE 1)

Enclosure (1)

CH-53E
TYPE EQUIPMENT CODE: AHXD
MISSION ESSENTIAL SUBSYSTEM MATRIX (MESM)

Assign alpha character (F) of the EOC code when the following system(s) are inoperative preventing the internal cargo transport mission. The aircraft is not capable of transporting bulk or palletized material, mobile equipment, or weapons (restricted to VMC). The aircraft is PMC, M or S.

CARGO SECURING EQUIPMENT
CARGO WINCH SYSTEM (NOTE 1)
RAMP SYSTEM

Assign alpha character (G) of the EOC code when the following system(s) are inoperative preventing the aerial refueling mission. The aircraft is not capable of conducting aerial refueling. The aircraft is PMC, M or S.

CABIN WINDOWS
PRESSURE REFUELING
PROBE IN-FLIGHT REFUELING SYSTEM

Assign alpha character (H) of the EOC code when the following system(s) are inoperative preventing the extended mobility mission. The aircraft is not capable of conducting long range tactical missions. The aircraft is PMC, M or S.

EXTENDED RANGE INTERNAL FUEL SYSTEM (NOTE 1)
CABIN ENGINE OIL REPLENISHMENT SYSTEM
GPS
HYDRAULIC IN-FLIGHT REPLENISHMENT SYSTEM
SATCOM (NOTE 1)

Assign alpha character (I) of the EOC code when the following system(s) are inoperative preventing the assault support mission utilizing night tactical systems. The aircraft is PMC, M or S.

AN/AAQ-16, 29 FLIR SENSOR (NOTE 1)
AN/AVS-7 HEADS UP DISPLAY (NOTE 1)
WINDSCREEN (CRAZING)

CH-53E
TYPE EQUIPMENT CODE: AHXD
MISSION ESSENTIAL SUBSYSTEM MATRIX (MESM)

Assign alpha character (J) of the EOC code when the following system(s) are inoperative preventing the external cargo transport mission. The aircraft is not capable of transporting cargo, equipment, and weapons external to the aircraft. The aircraft is PMC, M or S.

CARGO HOOK LOAD INDICATION SYSTEM (UNCERTIFIED WT LOADS ONLY)
DUAL POINT CARGO HOOK SYSTEM
EXTERNAL FUEL QTY SYSTEM
SINGLE POINT CARGO HOOK SYSTEM

Assign alpha character (K) of the EOC code when the following system(s) are inoperative preventing the shipboard operations mission. The aircraft is not capable of safe movement on, off, and about a ship during day, night and IMC. The aircraft is PMC, M or S.

ALTITUDE HOLD
ANTI-EXPOSURE SUIT BLOWER (NOTE 5)
BLADE FOLD SYSTEM
LANDING GEAR WARNING SYSTEM
PYLON FOLD SYSTEM
RETRACTABLE LANDING GEAR
ROTOR BRAKE

Assign alpha character (L) of the EOC code when the following system(s) are inoperative preventing night or IMC flight. The aircraft is not capable of day or night IMC field flight operations with necessary communication, IFF, navigation, and flight safety systems required by applicable NATOPS and FAA regulations. The aircraft is capable of day VMC flight only. The aircraft is PMC, M or S.

AFCS TRIM AND SAS
ALTIMETER ENCODER
ANTI-COLLISION LIGHTS (2 OF 2 REQUIRED)
BDHI
CABIN HEATER (NOTE 5)
CDI
CLOCK WITH SWEEP HAND
DIRECTIONAL GYRO SYSTEM
ENGINE ANTI-ICE SYSTEM (NOTE 5)
EXTERIOR LIGHTING
FLIGHT INSTRUMENTS
GROUND PROXIMITY WARNING SYSTEM (GPWS)
ICE DETECTION (NOTE 5)

CH-53E
TYPE EQUIPMENT CODE: AHXD
MISSION ESSENTIAL SUBSYSTEM MATRIX (MESM)

ILS GLIDE SLOPE
INTERIOR LIGHTING
MAGNETIC COMPASS
PITOT HEAT
RADAR ALTIMETER
TACAN
TRANSPONDER (MODE 3A, C)
UHF
UHF/ADF
VERTICAL SPEED INDICATOR
VHF (NOTE 1)
VOR
WINDSHIELD ANTI-ICE (NOTE 5)
WINDSHIELD WIPER

Assign alpha character (Z) of the EOC code when the following system(s)/conditions prevent the aircraft from being safely flyable. The aircraft is not capable of day, field flight operations under VMC with two-way communication and necessary aircraft and crew safety provisions. The aircraft is NMC, M or S.

AFCS COMPUTER
AFCS SERVO SYSTEM
AIRFRAME
ANTI-COLLISION LIGHT (1 OF 2 REQUIRED)
AUXILIARY POWER PLANT
BEARING MONITOR SYSTEM (BMS)
BIM INDICATOR
COCKPIT HYDRAULIC QUANTITY INDICATOR SYSTEM
CHIP DETECTOR SYSTEMS
EAPS
ELECTRICAL SYSTEMS
ENGINES
FIRE DETECTIONS SYSTEMS
FIRE EXTINGUISHER SYSTEMS
FLIGHT CONTROLS
FLIGHT REFERENCE (NOTE 3)
FUEL QTY INDICATING SYSTEM (NOTE 4)
FUEL SYSTEM
FUSELAGE
HELICOPTER EMERGENCY EGRESS LIGHTING SYSTEM (HEELS)
HYDRAULIC ACCUMULATOR (1 OF 2)
HYDRAULIC/PNEUMATIC SYSTEMS
ICS (PILOT/COPILOT AND CREW CHIEF REQUIRED)
INSTRUMENTS/INSTRUMENT SYSTEMS (WUC 51 SERIES THAT AFFECT FLIGHT SAFETY)

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APPENDIX H. CH53E NAVSUP WSS REPARABLE INVENTORY POSTURE (WHOLESALE)

United States Navy Reparable Wholesale Inventory 10 Yrs Stratification Analysis										
Total Reparable in Thousands of Dollars				Not included in Total		* = Mechanicsburg and Philadelphia reparable totals combined all other years are reparable Philadelphia totals				
Year	Approved Acquisition Objective (AAO)	War Reserve Material (inc. in AAO)	In-Transit Stock	Economic Retention Stock (ERS)	% ERS of total Reparable Stock	Contingency Retention Stock (CRS)	% CRS of total Reparable Stock	Potential Security Assistance Stock	Potential Reutilization/ Disposal Stock	Total
2004*	\$17,214,817	\$34,686	\$2,558,115	\$1,545,867	7%	\$801,690	4%	\$214,302	\$290,324	\$22,410,813
2005*	\$16,533,865	\$35,618	\$612,595	\$1,639,018	8%	\$1,037,477	5%	\$243,990	\$108,834	\$19,931,789
2006	\$13,783,513	\$36,000	\$433,609	\$969,501	6%	\$519,118	3%	\$208,940	\$67,633	\$15,773,374
2007	\$11,637,530	\$34,600	\$390,328	\$903,954	7%	\$390,824	3%	\$142,750	\$68,868	\$13,391,504
2008	\$11,386,442	\$32,426	\$2,526,547	\$899,729	6%	\$488,493	3%	\$149,641	\$62,654	\$15,363,865
2009	\$11,880,325	\$44,142	\$1,631,387	\$1,037,801	7%	\$321,923	2%	\$134,163	\$64,168	\$14,935,604
2010	\$13,916,467	\$42,882	-\$7,566	\$937,292	6%	\$232,920	2%	\$61,826	\$64,727	\$15,143,840
2011	\$14,623,314	\$0	\$4,990	\$1,124,031	7%	\$288,105	2%	\$49,487	\$26,304	\$16,066,744
2012	\$8,442,757	\$0	\$3,485	\$1,001,748	10%	\$760,550	7%	\$28,094	\$21,080	\$10,229,620
2013	\$8,717,721	\$0	\$233,178	\$614,889	5%	\$1,894,382	17%	\$24,067	\$17,540	\$11,477,710

Figure 31. U.S. Navy 10 Year Reparable Wholesale Profile

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APPENDIX I. POISSON INVERSE USER DEFINED FUNCTION

- User-defined function to provide required quantity of spares for expected number of attritions (failures) during a given period.
-
- Function poisson_inverse(p, lambda)
- 'p is cumulative probability
- 'lambda is mean of the Poisson distribution
- 'This routine truncates the result at xmax
-
- Dim x As Integer
- If lambda > 60 Then
- x = Round(WorksheetFunction.NormInv(p, lambda, Sqr(lambda)), 0)
- poisson_inverse = x
- Else
- Const xmax = 100
- For x = 0 To xmax
- poisson_inverse = x
- If Application.WorksheetFunction.Poisson(x, lambda, True) >= p Then Exit Function
- Next x
- MsgBox "poisson_inverse(" & Format(p, "0.00%") & ") was truncated at " & Val(xmax) & "!", vbExclamation
- End If
- End Function
-
-
-
- **Function developed by Keebom Kang, 2013 GSBPP; Naval Postgraduate School**

Figure 32. Poisson Inverse User Defined Function (from Kang, 2013)

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